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June 1984

WATER RESOURCES BRANCH
Ministry of the Environment
1 St. Clair Avenue West
Toronto, Ontario
M4V 1K6

STATISTICAL CHAIN-OF-LAKES MODEL

FINAL REPORT

ACRES

June 12, 1984
P6746.09.02

Dr. L. Logan
Water Resources Branch
Ministry of the Environment
Quality Protection Section
1 St. Clair Avenue W
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Toronto, Ontario
M4V 1K6

Dear Dr. Logan, Statistical Chain-of-Lakes Model

Following receipt of your comments on our draft report we have incorporated these as appropriate and are pleased to submit our final report on the Statistical Chain-of-Lakes Model. This report describes development and testing of a model to simulate flow conditions in a "Chain-of-Lakes" and, with the model which was supplied to you in June 1983, fulfills our terms of reference for this study.

We trust that the model is of value to you in your ongoing work in assessing the effects on water quality of acid precipitation and and we would like to take this opportunity to thank you for your assistance during the model development and testing.

Yours very truly,

I. K. Hill
Project Manager

IKH:rs

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1 - SUMMARY

1 - SUMMARY

The impact of acid deposition on the aquatic ecosystems of the Canadian Shield region of central Ontario has, in recent years, become the subject of increased study. An important component in this study is the evaluation of acidity transmission by surface water.

To this end, a model was required to estimate local runoff and to simulate the movement of runoff through a stream network. Since stream networks in the region of interest are dominated by interconnected lakes, these networks are represented in the model as interconnected chains-of-lakes. The model is divided into three parts. The first part is used to calculate subbasin runoff, the second part is used to route the subbasin runoffs through the system and the third optional part can be used to calibrate the model for a specific basin.

The runoff prediction utilizes equations to estimate average monthly runoff for any basin of interest. The equations were derived from a multiple linear regression analysis and are applicable only to basins similar to those used in deriving the equations. This limits the use of the equation to basins up to about 750 km^2 in area located in the Canadian Shield region of central Ontario (from Lake Simcoe to Sudbury and east from Georgian Bay to Pembroke on the Ottawa River). The variables incorporated in the runoff prediction equations are either physiographically or climatologically based.

Two separate sets of runoff prediction equations were developed. One set of equations is based on correlations of historic sequential data while the other set is based on correlations of ranked data.

The relationships which were derived using historic sequential data are applicable to

- replicating or estimating runoff in a particular historic month in an ungauged catchment

- reproducing the statistical behavior of monthly runoff (i.e., mean, standard deviation, skew of the monthly distribution). These estimates will also replicate data for a specific historic month.

The relationships which were developed using ranked data are applicable to

- reproducing the statistical behavior of monthly runoff (i.e., mean, standard deviation, skew of the monthly distribution). These estimates will not replicate data for a specific historic month.

The second part of the model, the routing model, is deterministic. This part routes the individual subbasin runoffs through a stream network. An estimate of discharge is provided at selected points, resulting from both local runoff and from inflows originating in upstream basins. In addition to accumulating contributions from upstream basins, the routing model accounts for natural regulation from major unregulated lakes and controlled regulation from the operation of river or lake structures.

The third portion of the model may optionally be used for calibrating the model to specific drainage basins where historic discharge data for the basin is available. The two calibration techniques which can be optionally selected within this part of the model are

- historic replication of a specific basin discharge record

- improvement of the runoff regression equations for a specific data record.

The historic replication technique can be used for determining the distribution of runoff within a basin which has a long historic record of measured discharges. The technique cannot be used for extending data beyond the period of measurement at a downstream gauging station. This replication adjusts the basin time series response to perfectly match a single downstream gauge. The adjustment is then distributed over the subbasin on the basis of subbasin runoff, as computed by the regression equations, as opposed to using the common technique of prorating based on subbasin area alone. Although the selected approach is physically realistic, it is not possible to judge its accuracy using the available data base.

The runoff regression equation improvement technique can be used for extending data to periods when discharge records are not available but climatic data is available.

The South Branch Muskoka River was selected for testing the chain-of-lakes model. Rule curves and historic lake level data were used for operating and verifying the model. The results of three test runs are presented. These runs are

- historic replication (including a month-by-month calibration)

- statistical simulations using

  - historic sequential runoff prediction equations (including calibration to improve the runoff prediction equations)

  - ranked runoff prediction equations (including calibration to improve the runoff prediction equations).

The results shows that considerable adjustment is required to calibrate the model on a month-by-month basis.

Similarly, calibration using an improvement to the runoff regression equations resulted in significant changes to the relationships.

A comparison of the two statistical simulations shows that the ranked approach is better suited for data extensions where the statistical behavior of runoff is of more concern than particular historic runoffs.

From the results of the test cases on the South Branch Muskoka River, and from the natural runoff prediction scatter diagrams, it can be concluded that flow estimates for ungauged uncalibrated catchments are only reliable within a factor of approximately two. Flow estimates using the calibration routine of the model will be very much more reliable, although the accuracy of flow estimates for ungauged subbasins in a gauged basin can not be evaluated using the current data base. It is therefore recommended that the model be tested on a watershed for which subbasin discharge data is available.

There are several appendixes to this report which give additional details of the study as follows:

- discharge calculations for the routing model

- details of the calibration procedures

- user's guide to the input data

- example input and output for a historic replication run for the South Branch Muskoka River.

2 - INTRODUCTION

2 - INTRODUCTION

In recent years, the phenomenon of acid deposition has become a serious environmental problem. The most widely publicized result of acid rain is the destruction of many forms of life within any given lake. This destruction of life occurs once the pH level has been reduced to a critical level through accumulation of acid precipitation.

In order to assist in the monitoring and evaluation of the effects of acid deposition on the ecosystem, there is a need to predict changes in pH levels of lakes for a given level of acid deposition. As part of the response to this need, the object of this study is the development of a model for predicting or simulating flow at any point within a stream network. Ultimately, the model is to be used to calculate the hydrologic input for a water quality model used to simulate water quality effects of acid rain deposition.

Acid deposition exists throughout Canada, however, the effects are most acute in regions which do not have a natural buffer, such as limestone. Of particular concern is the Canadian Shield region of central Ontario. The thin soil and bedrock offer little buffering. Because of its significance, this region has been selected for detailed study. The region is characterized by thousands of lakes with a wide range of sizes and configurations. On a monthly basis, the flow regime of a stream network in this region is usually controlled by precipitation and lake storage, with in-channel storage having little effect. Consequently, a drainage basin or stream network may be modeled as a chain of lakes.

The development of a chain-of-lakes model is potentially very complex. However, the model presented herein is simple in both its theory and in its application.

The model can be considered in three parts. The first part is statistically based and involves the development of runoff prediction equations from physiographic and climatologic data. The second part of the model is physically based and is primarily a routing model with the focus on routing runoff from individual basins through a stream network, or a network of basins. The third portion of the model may optionally be used for calibrating the model to a specific drainage basin.

In this report, the development of the runoff prediction equations is discussed first. Subsequently, the flow prediction model is described. It includes the results of the runoff prediction equations and routing and calibration techniques. Finally, application of the model to the South Branch Muskoka River is discussed. The south Muskoka drainage basin was selected for verification purposes because of the availability of a comprehensive data base. Appendix E provides a user's guide to the input data which is required to run the model. Appendix F is a test run for the South Branch Muskoka River, including input data files and an output listing. Other appendixes list data used for the runoff prediction correlations and provide greater detail of the routing model than appears in the main text.

3 - NATURAL RUNOFF PREDICTIONS

3 - NATURAL RUNOFF PREDICTIONS

Multiple regression analyses were used to develop monthly natural runoff prediction equations for the Canadian Shield region of central Ontario. The relationships are based on readily available climatologic and physiographic data. Special care was taken to ensure that the resultant relationships were physically meaningful. However, the reliability of the prediction equations is influenced by the meagre data base which is available.

In any application of statistics to hydrology, particularly for analyses using limited data, there are certain dangers, misuses and misconceptions which must be recognized. In this study, these possible problems are especially relevant and should be mentioned. Yevjevich (Reference 1) has stated them as follows.

(a) Expectations are often greater than the available data and the best results which statistical methods can produce.

(b) False expectations that statistical methods may in some way replace the scarcity or unreliability of data, which is impossible.

(c) The tendency to replace the necessary judgment and interpretation of physical facts by statistical computations or statements.

Within this section, techniques for developing a long period of reference hydrology are discussed. This long period reference hydrology is then available for analyzing the

long-term effects of acid precipitation fallout. Data extension is frequently required for developing long period reference hydrology and possible extension techniques are presented along with the two techniques which were selected for detailed investigation.

The remainder of this section describes these extension techniques and the development of the statistical runoff prediction equations. A discussion of each of the following is included in this section:

- techniques for data extension
- data availability
- methods of analysis
- results.

3.1 - Techniques for Data Extension

There are various techniques that can be used for extending streamflow records to obtain a larger synthetic record for use as reference hydrology. This long period reference hydrology might be of interest for analyzing the long-term effects of acid precipitation fallout. Some of the available techniques are listed and discussed briefly as follows.

(a) Runoff/Runoff Correlations

Correlations of this type can be made between short- and long-term gauging stations in the same river basin and/or in nearby basins. This technique is applicable to many circumstances, such as the original Serpent River

model, but could not be easily used in a general manner for estimates on a totally ungauged catchment as required in the current study.

(b) Rainfall/Runoff Correlations

Correlations of this stype can be made between long-term rainfall stations and short-term streamflow gauging stations, provided both types of stations are located in a homogenous climatologic and physiographic region. Unfortunately, in many circumstances rainfall stations are not well located for obtaining consistent estimates of basinwide rainfall. Consequently, the correlations are weak and the standard error of estimate of runoff from rainfall observations is large.

The principle analyses for the current study use rainfall/runoff correlations extensively. However, in the current case the errors associated with the weak correlations are partially corrected by calibration against downstream flow data. This calibration is performed for an ungauged subcatchment by adjusting the general runoff relationships, so that the total discharge from the catchment matches the records for the downstream gauge. A detailed description of this calibration technique is presented in Section 4.3.2.

(c) Markov Modeling

Synthetic streamflow generation can be done using a Markov type model. Such models view streamflow as a time series of serially dependent values, where each value has a deterministic component and a random component.

The deterministic component can be comprised of a transfer function to convert precipitation to runoff. To apply Markov type modeling to the current study would require an appropriate transfer function. The limitations imposed by the current data set prevent application of this highly specialized hydrologic tool.

(d) Ranked Rainfall/Runoff Correlation

Ranked rainfall/runoff correlation is a correlation of rainfall in a basin with runoff, on the basis of frequency of occurrence. This method attempts to compensate for inadequate disposition of rainfall stations in or near a basin by bypassing the deterministic relationship between rainfall and runoff to directly consider the probabilistic nature of the hydrologic cycle. The ranked correlation approach assumes that both the basin and the meteorologic station are located in the same climatic zone and that their long-term precipitation density functions are similar. The ranked correlation approach involves reproducing the statistical behavior of a basin without regard for reproducing or predicting specific historic runoff. The method is therefore most applicable when analyzing long-term trends and overall basin behavior.

The two techniques which have been adopted in this study are

- rainfall/runoff correlation
- ranked rainfall/runoff correlation.

Both methods can be used for extending the discharge record beyond the period of available discharge data. However, if an estimate of runoff for a particular historic month is

required, then only the historic sequential rainfall/runoff correlation is applicable. For general extensions of data, either technique can be used. However, Section 5 (Test Results) demonstrates that the statistical behavior of the basin is reproduced more closely using the ranked rainfall/runoff correlation technique.

3.2 - Data Availability

In total, 13 drainage basins ranging in size from 22 to 741 km^2 were selected for analysis. These drainage basins were selected based on the availability of natural discharge records. The selected basins are illustrated on the location map in the pocket at the back of this report.

The rest of this section presents information concerning the discharge data, the physiographic characteristics, and the climatologic data.

3.2.1 - Streamflow

Monthly discharge data was obtained from Water Survey of Canada (WSC) publications (References 2, 3 and 4) and is tabulated in Appendix A. The period 1970 to 1981 was selected for analysis since few gauges predated 1970. The available period of record for each of the 13 gauges is illustrated on the bar chart in Figure 1.

3.2.2 - Physiographic Characteristics

All physiographic data were obtained from 1:50 000 scale topographic maps published by the Surveys and

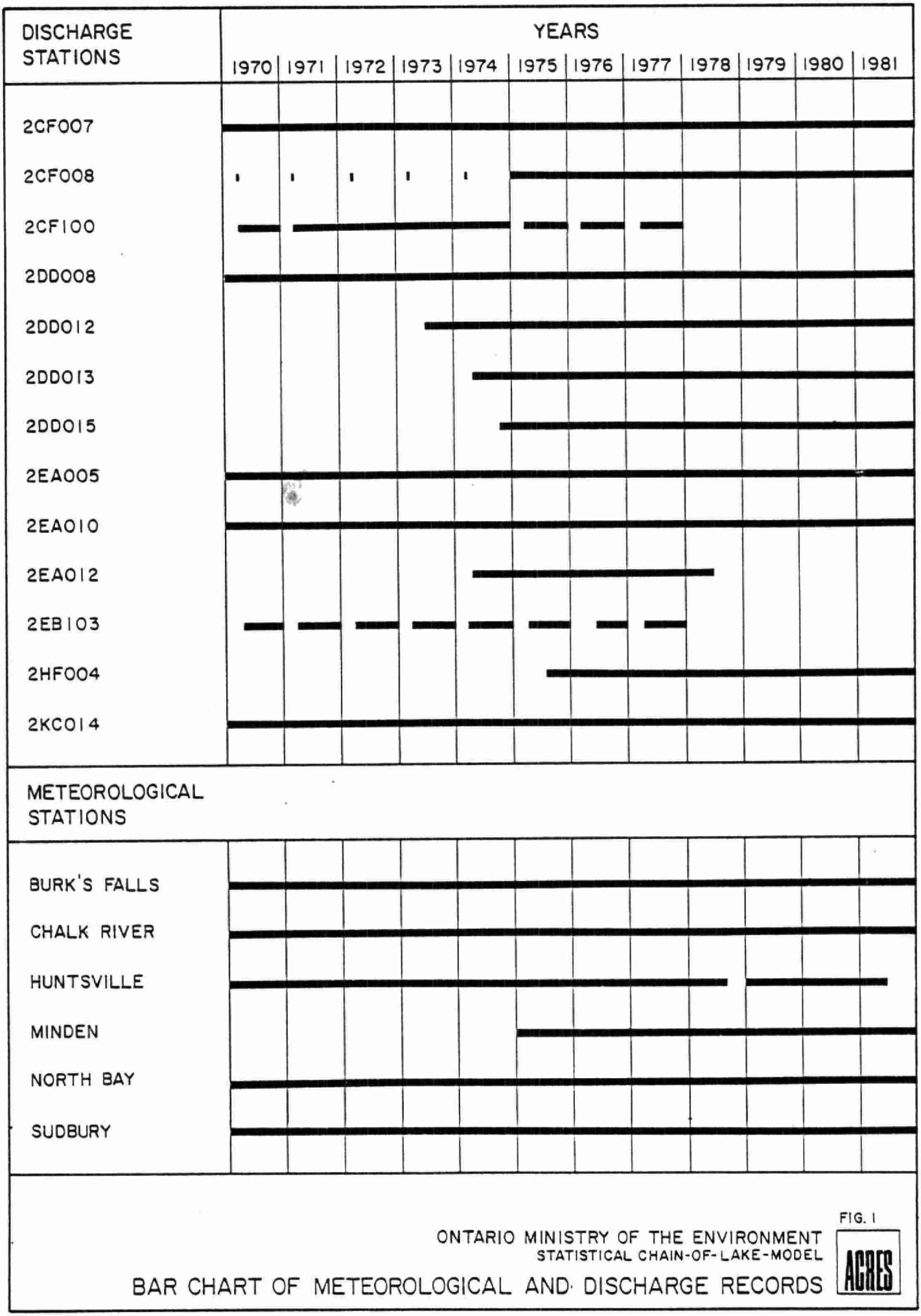

FIG. 1

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

BAR CHART OF METEOROLOGICAL AND DISCHARGE RECORDS

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Mapping Branch of the Department of Energy, Mines and Resources. The data were obtained by measurements using a digitizer linked directly to Acres VAX computer. The map sheet reference numbers, which are applicable to each of the 13 selected basins, are tabulated in Table 1 along with other pertinent physiographic data.

The particular physiographic data which were measured are discussed below.

(a) Total Basin Area - A_B

The total basin areas tributary to each stream gauge are published by WSC. These areas were checked to ensure that the drainage basins which were drawn on the topographic maps corresponded to the basins as defined by WSC.

(b) Area of Lakes - A_L

The area of lakes in each of three size categories was measured for each basin. These sizes are

- less than 0.01 km^2
- from 0.01 to 0.5 km^2
- greater than 0.5 km^2.

As discussed further on in this report, the available data base was not suitable for regression on a large number of independent variables. Consequently, these three categories were later lumped together into a total area of lakes for each basin.

TABLE 1

SUMMARY OF PHYSIOGRAPHIC DATA
USED IN THE REGRESSION ANALYSIS

River	Gauge Number	Area of Basin	Area of Swamps	Area of Lakes	Climatological Station	1:50000 Topographic Map Index
N. Magnetawan	2EA005	172.0	10.1	16.5	Burk's Falls	31E/11, 14
N. Magnetawan	2EA010	149.0	3.8	4.7	Burk's Falls	31E/11, 14
Shawanaga River	2EA012	235.0	37.6	24.2	Burk's Falls	41H/8, 9 31E/12
Whitson River	2CF007	117.0	0.4	0.0	Sudbury	41I/10, 11E
Whitson River	2CF008	155.5	29.1	8.7	Sudbury	41I/10, 11E
Vermilion River	2CF100	635.0	45.1	61.4	Sudbury	41I/10W, 11E, 14E, 15W 41P/3E
Duchesnay River	2DD008	90.0	2.6	0.9	North Bay	31L/5, 6W
Veuve River	2DD012	741.0	66.5	23.4	North Bay	41I/7, 8, 9, 10
La Vase River	2DD013	70.4	3.6	0.2	North Bay	31L/3, 6
Commanda Creek	2DD015	106.0	10.8	5.6	North Bay	31E/13, 14
Rosseau River	2EB103	130.0	10.1	4.9	Huntsville	31E/4, 5, 6
Bob Creek	2HF004	22.0	2.9	0.5	Minden	31D/15 31E/2
Indian River	2KC014	443.0	21.0	11.0	Chalk River	31F/11, 12E, 13E, 14

(c) Area of Swamps - A_s

The area of swamps was measured for each basin. The definition of swampland is dependent on topographic mapping detail because the swamp area was measured from areas depicted symbolically on the maps as swampland. The area of swamps normally varies throughout the year and from year to year.

3.2.3 - Climatologic Data

Climatologic stations with sufficient record, that are within or near a basin, were selected from the Climatological Station Data Catalogue for Ontario (Reference 5). The selected stations are

- Sudbury
- North Bay
- Burk's Falls
- Huntsville
- Minden
- Chalk River.

The particular station which applies to each of the drainage basins is listed in Table 1. The stations are also shown on the location map in the pocket of this report. Figure 1 shows the available period of record for each station. Appendix B is a compilation of the pertinent data for each of the 6 stations. This data was compiled from Monthly Records of Meteorological Observations in Eastern Canada by the Atmospheric Environment Service (AES) (Reference 6).

The particular climatologic data which was tabulated is discussed below.

(a) Precipitation - P

The total monthly precipitation for each month was tabulated.

(b) Mean Monthly Temperature - Tmax or Tmin

Three individual measures of the mean temperature for each month are available based on

- maximum daily temperature
- minimum daily temperature
- mean daily temperature.

The mean daily temperature which is tabulated by AES is just the average of maximum and minimum daily temperatures. Consequently, only the mean monthly temperatures based on maximum and minimum daily temperature were extracted from the records for the purpose of this study.

(c) Degree Days Above Freezing - Dmax or Dmin

The number of degree days above freezing (0°C) for each month was derived from AES published records. Two measures of this parameter were used--based on either the maximum daily or minimum daily temperature.

In the summer, this variable is equivalent to the average temperature and consequently was not tabulated. However, in the winter and spring, this variable reflects the importance of the number of melt degrees rather than the overall temperature.

3.3 - Method of Analysis

The objective of this analysis was to develop monthly natural runoff prediction equations for ungauged catchments in the Canadian Shield region of central Ontario. The previously discussed independent variables (A_B, A_L, A_S, P, Tmax, Tmin, Dmax, Dmin) were used in a multivariate regression analysis to derive these prediction equations. A stepwise multiple linear regression computer program was used for the analysis. The general characteristics of this program and the actual analysis which was undertaken are discussed in the following two subsections.

3.3.1 - Regression Analysis Computer Program

The program performs the stepwise regression analysis using a simple correlation coefficients matrix. Any combination of one dependent variable and one or more independent variables may be selected for analysis, using the input either directly or transformed.

In the stepwise procedure, independent variables are added one at a time to the regression, giving the following intermediate equations

$$Y = B_0' + B_1'X_1 \qquad (1)$$

$$Y = B_0'' + B_1''X_1 + B_2''X_2 \qquad (2)$$

$$Y = B_0'''' + B_1''''X_1 + B_2''''X_2 + B_3''''X_3 \qquad (3)$$

In this manner, it is possible to obtain valuable statistical information on the improvement in predictive capability at each step of the calculation.

At each step, those independent variables not included in the regression are inspected to find the one that will give the greatest reduction in the variation of Y. This variable is then tested for significance; i.e., the computed F-ratio of the variable is compared to the supplied critical F-value. If the computed value is greater than the critical value, the variable is considered significant and is added to the regression solution. Where appropriate, "forced independent variables" are defined to always be included in the equations and are not tested for significance.

After each new variable has been added, those variables already in the regression are inspected to see if any of them can now be deleted because their contribution to the reduction in the variation of Y is no longer significant. Those variables which have a computed F-ratio less than the critical value are considered insignificant and are deleted from the regression solution.

This process is continued until no more variables are added or deleted. Thus, the final regression solution contains only those variables that are statistically significant (except possibly forced variables). The general equation which results is thus

$$Y = B_0 + B_1X_1 + B_2X_2 + \ldots B_nX_n \qquad (4)$$

Under user control, it is possible to force one or more of the independent variables into the regression solution. These variables are added before any other variables, with no regard for statistical significance. The remaining independent variables are then added to

the equation in the normal stepwise procedure as outlined in the preceding paragraphs. Once a variable has been forced into the regression, it will be kept regardless of the statistical significance.

The application of transformed variables can alter the linear form of Equations 1 through 4 and, the multiple linear program can then be used for general multivariate regression analysis. Two sets of transformations were investigated for application in the current study. These transformations are the following.

(a) Log Transform of the Dependent and Independent Variables

Substituting log Y, log X_1, log X_2, etc, for Y, X_1, X_2, etc, in Equations 1 through 4 results in the following general equation

$$\log Y = B_0 + B_1 \log X_1 + B_2 \log X_2 + \ldots B_n \log X_n \qquad (5)$$

This equation simplifies to the following Power Law Relation

$$Y = 10^{B_0} \; X_1^{B_1} \; X_2^{B_2} \ldots X_n^{B_n} \qquad (6)$$

(b) Log Transform of the Dependent Variable

Substituting log Y for Y in Equations 1 through 4 results in the following general equation

$$\log Y = B_0 + B_1 X_1 + B_2 X_2 + \ldots + B_n X_n \qquad (7)$$

This equation reduces to the Exponential Relation which follows

$$Y = 10^{B_0} \; b_1^{X_1} \; b_2^{X_2} \ldots b_n^{X_n} \qquad (8)$$

where

$$b_1 = 10^{B_1}, \; b_2 = 10^{B_2}, \text{ etc}$$

3.3.2 - Alternative Analytic Approaches

There are two alternative approaches which were investigated for the regression analyses. These two approaches can be simply described as a one-step analysis and a two-step analysis. Each technique is described briefly below, followed by a general discussion of the relative merits and limitations of each.

(a) One-Step Analysis

Analyses using the one-step technique involve determining monthly relationships as follows.

$$R = \text{Function(Physiographic Data, Climatologic Data)} \qquad (9)$$

where R is the monthly average discharge for a natural catchment.

Both dependent and independent variables are lumped together into one long record containing all of the years of record for all of the basins for any particular month of the year. This technique is commonly used in hydrologic regressions

and is called the station-year method by Yevjevich (Reference 1). It must be recognized that the effective number of observations is much smaller than the total number of observations. Physiographic data (A_B, A_L, A_S) for the independent observations are repeated in blocks for each basin and are not variable throughout the entire set of observations. Similarly, the same meteorologic station is used for several basins and the precipitation and temperature variables are also repeated in blocks. Because of the obvious mutual correlation of these variables, it is readily apparent that the total sample size can only provide as much information as some lesser number of totally independent observations. In this study the total data set contains approximately 100 observations for each month. However, the equivalent number of independent sets of observations would be much less.

(b) Two-Step Analysis

Analyses using the two-step technique involve separately determining the following monthly relationship for each basin

$$R = \text{Function(Climatologic Data)} \qquad (10)$$

This analysis results in a set of coefficients which describe the runoff in each particular basin (i.e., B_0, B_1, B_2, etc, from Equation 4 for each basin). The second half of the two-step analysis involves explaining the variation in these coefficients as follows

$$B_0, B_1 \ldots B_n = \text{Functions(Physiographic Data)} \quad (11)$$

The derivation of natural runoff for an ungauged catchment therefore requires two steps as follows.

- Determine the coefficients $B_0, B_1 \ldots B_n$ based on the basin-specific physiographic data (from Equation 11).

- Determine the basin runoff based on the coefficients and climatologic data (from Equation 10).

The two-step technique has the following advantages.

- The data limitations are readily apparent at all times. It is always immediately apparent that each regression of the form of Equation 10 is based on a relatively short record (4 to 12 years in the current study).

- There is no compromise of formal statistical rules concerning dependency and independency.

The one-step technique has the following advantage.

- The total number of regression analyses is greatly reduced. In the current study, 15 or 16 runs would be required for the two-step approach as opposed to 1 run for the one-step approach. When compounded by the requirement for 12 monthly regressions, it is apparent that the one-step technique is much simpler and more straightforward.

A test was performed using both techniques for the month of May. An evaluation of the final results was done using comparisons of observed and estimated discharges. It was discovered that the final estimates using both techniques were quite similar. The standard error of estimate was marginally lower for the one-step approach on 10 of the 13 basins and marginally lower for the two-step approach on the other 3. No distinct pattern was observed for this variation between the techniques. Because of the computational and data handling advantages of the one-step technique, it was adopted for all of the remaining regression analyses in this study.

3.4 - Results of Regression Analysis

The analyses were done using the multiple linear regression computer program described in Section 3.3.1.

The independent variables which were used in the initial regressions are the following (where i refers to the current month).

- Monthly precipitation - P_i, P_{i-1}, P_{i-2}, P_{i-3}, P_{i-4} (m)

- Mean monthly temperature based on the maximum daily temperature $Tmax_i$, $Tmax_{i-1}$

- Mean monthly temperature based on the minimum daily temperature $Tmin_i$, $Tmin_{i-1}$

- Degree days above 0°C based on the daily maximum temperature - $Dmax_i$, $Dmax_{i-1}$, $Dmax_{i-2}$, $Dmax_{i-3}$

- Degree days above 0°C based on the daily minimum temperature - $Dmin_i$, $Dmin_{i-1}$, $Dmin_{i-2}$, $Dmin_{i-3}$

- Area of basin - A_B (km^2)

- Area of lakes - A_L (km^2)

- Area of swamps - A_S (km^2)

The variables Dmax and Dmin were only included in the analysis for the period from November to April when the impact of melt degrees could be significant.

The dependent variable was the current monthly recorded natural discharge, R_i.

The multiple linear regression computer program described in Section 3.3.1 was used for general multivariant regression analyses using the following transformations.

- Direct independent and dependent variables (linear relation).

- Logarithm of both independent and dependent variables (power law relation).

- Logarithm of dependent variable and direct independent variables (exponential relation).

It was found that satisfactory results could only be obtained for a linear relation. The power law relation created unacceptable anomalies if one or more of the independent variables was very small. The exponential relation did not have this deficiency, however, the results were not as good

as for the simple linear relation. Consequently, all of the final regression equations are multiple linear equations.

Many alternative combinations of variables were tested before the final equations were derived. The F-statistic at the 90 percent confidence level was used as the criterion of acceptance of independent variables into the predictive equation. However, this was tempered with judgment, when considering acceptance or rejection of variables, based on the physical significance of the variables.

Precipitation and area of basin are always present in the relationships because of the physical relation between the runoff and the volume of water ($P \times A_B$) falling on the basin. Precipitation was initially included for the current month and also lagged by up to 4 months (P_i to P_{i-4}). It was found that in some months the precipitation occurring several months prior to the current month was statistically more significant than the current months precipitation. For basins ranging in size from 22 to 741 km^2, this anomally seems physically unreasonable. Consequently, the independent variable describing precipitation was changed to the average precipitation for a period which varied in duration from 1 to 4 months. There was also a secondary advantage to this choice because the number of independent variables was reduced, thereby providing more degrees of freedom to the final relationship.

The general regression equations which resulted for both the ranked and historic sequential rainfall/runoff correlations are as follows.

<u>April to November</u>

$$R = a_1 + A_B(a_2P + a_3) + A_2(a_4P + a_5) + A_5a_6 \qquad (12)$$

where

a_1 to a_6 are constant coefficients which vary from month to month

P is either $(P_i + P_{i-1})/2$ or $(P_i + P_{i-1} + P_{i-2})/3$ or $[P_i + (P_{i-1} + P_{i-2} + P_{i-3})/3]/2$, depending on the specific month

December to March

$$R = a_1 + A_2 a_2 + A_B[a_3 + P(a_4 + a_5 D)] \quad (13)$$

where

D is the monthly degree days above 0°C. D is either $(Dmax_i + Dmax_{i-1})/2$, $(Dmin_i + Dmin_{i-1})/2$ or $Dmin_i$, depending on the specific month.

The general relationship for April to November (Equation 12) can be reduced to the following basin-specific runoff equation.

$$R = \alpha_1 + \beta_1 P \quad (14)$$

where

$$\alpha_1 = a_1 + a_3 A_B + a_5 A_L + a_6 A_s$$

$$\beta_1 = a_2 A_B + a_4 A_L$$

Similarly the general relationship for the December to March period (Equation 13) can be reduced to the following basin-specific runoff equation

$$R = \alpha_2 + \beta_2 P + \gamma_2 PD \qquad (15)$$

where

$$\alpha_2 = a_1 + a_2 A_L + a_3 A_B$$

$$\beta_2 = a_4 A_B$$

$$\gamma_2 = a_5 A_B$$

These reduced equations are simple linear rainfall/runoff prediction equations. The comparison of the one-step and two-step regression techniques which was discussed in Section 3.3.2 is analogous to a comparison between Equations 12 and 14 and Equations 13 and 15. In the two-step analysis, the coefficients α_1, α_2, β_1, β_2 and γ_2 would be determined for each of 13 basins. Prediction equations would then be derived for α_1, α_2, β_1, β_2 and γ_2, based on physiographic characteristics for each basin. In the one-step analysis, α_1, α_2, β_1, β_2 and γ_2 are derived implicitly within Equations 12 and 13 using an overall lumped data set. As can be seen, the final prediction equations, using either the one-step or the two-step technique, would have similar forms.

3.4.1 - Historic Sequential Correlations

The regression analyses produced a set of coefficients (a_1 to a_6) for both general equations (Equations 12 and 13). These coefficients are tabulated in Table 2. The scatter diagrams relating measured and calculated runoff for each month are plotted in Figures 2 to 7.

TABLE 2

COEFFICIENTS FOR HISTORIC SEQUENTIAL CORRELATIONS

General Equation: (April to November)

$$R = a_1 + A_B (a_2 P + a_3) + A_L (a_4 P + a_5) + a_6 A_s$$

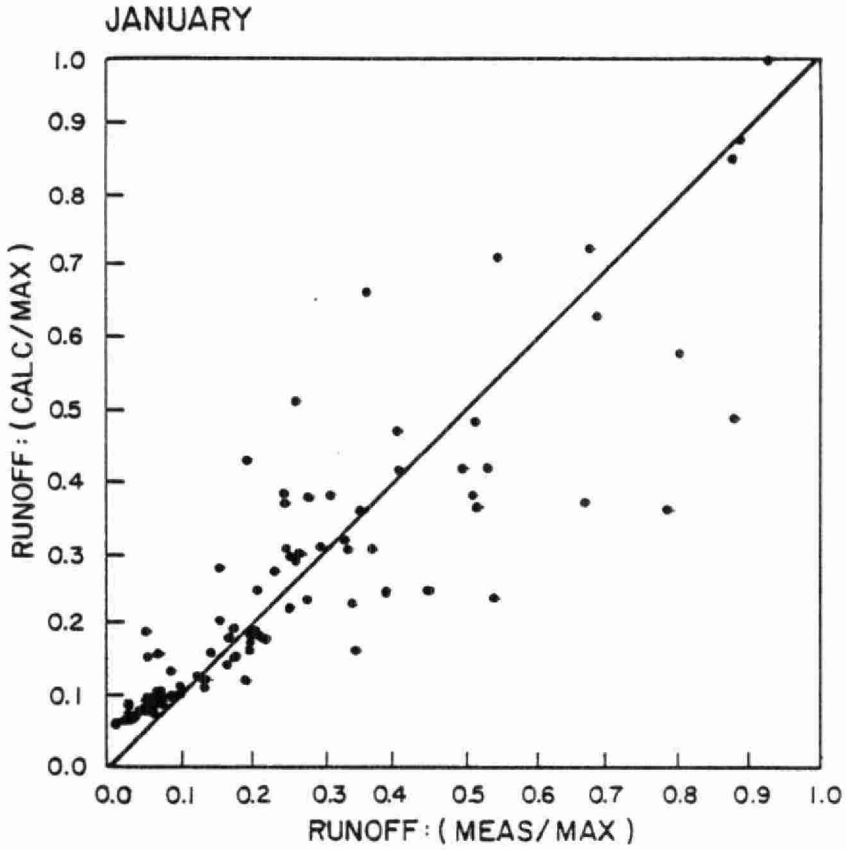
	Precipitation (m)	a_1	a_2	a_3	a_4	a_5	a_6	r^{2*}	Significant r^{2**} (90 %)	(95%)	SEE (m^3/s) *	$\bar{Q}$ (m^3/s) *
Apr	$(P_i + P_{i-1})/2$	-0.926	0.529	0.020	0.0	-0.267	0.267	0.83	0.64	0.80	6.48	13.8
May	$(P_i + P_{i-1})/2$	-0.384	0.051	0.023	0.0	0.213	-0.108	0.82	0.64	0.80	3.35	6.91
Jun	$(P_i + P_{i-1})/2$	0.071	0.119	0.0	0.0	0.114	-0.074	0.80	0.64	0.80	1.33	2.42
Jul	$(P_i + P_{i-1} + P_{i-2})/3$	0.399	0.064	0.0	0.927	0.0	-0.066	0.67	0.64	0.80	1.10	1.52
Aug	$(P_i + P_{i-1} + P_{i-2})/3$	0.080	0.051	0.0	0.522	0.0	-0.038	0.64	0.64	0.80	0.86	1.13
Sep	$(P_i + P_{i-1} + P_{i-2})/3$	0.050	0.170	-0.0086	0.0	-0.022	0.0	0.65	0.62	0.70	1.58	1.76
Oct	$(P_i + P_{i-1} + P_{i-2})/3$	0.064	0.313	-0.017	0.0	-0.024	0.0	0.78	0.62	0.70	1.87	2.94
Nov	$(P_i + (P_{i-1} + P_{i-2} + P_{i-3})/3.0)/2$	-0.060	0.296	-0.012	0.0	0.0	0.0	0.66	0.48	0.57	2.21	3.30

General Equation: (December to March)

$$R = a_1 + a_2 A_L + A_B (a_3 + P (a_4 + a_5 D))$$

	Precipitation (m)	Degree Days ($0^{\circ}C$)	a_1	a_2	a_3	a_4	a_5	r^2	Significant r^{2**} (90%)	(95%)	SEE (m^3/s)	$\bar{Q}$ (m^3/s)
Dec	$(P_i + P_{i-1})/2$	$(Dmax_i + Dmax_{i-1})/2$	0.161	0.058	0.0	0.036	0.0013	0.84	0.64	0.80	1.13	2.71
Jan	$(P_i + P_{i-1})/2$	$(Dmax_i + Dmax_{i-1})/2$	0.244	0.048	0.0	0.025	0.00066	0.76	0.64	0.80	0.59	1.33
Feb	$(P_i + P_{i-1})/2$	$(Dmin_i + Dmin_{i-1})/2$	0.312	0.042	0.0	0.018	0.049	0.82	0.64	0.80	0.90	1.40
Mar	$(P_i + P_{i-1} + P_{i-2})/3$	$Dmin_i$	1.033	-0.039	0.0071	0.0	0.043	0.76	0.64	0.80	2.80	3.90

* r^2 is the coefficient of determination
* SEE (m^3/s is the standard error estimate
* $\bar{Q}$ (m^3/s) is the mean monthly discharge for all stations used in the analysis
**Assuming 10 effective independent observations



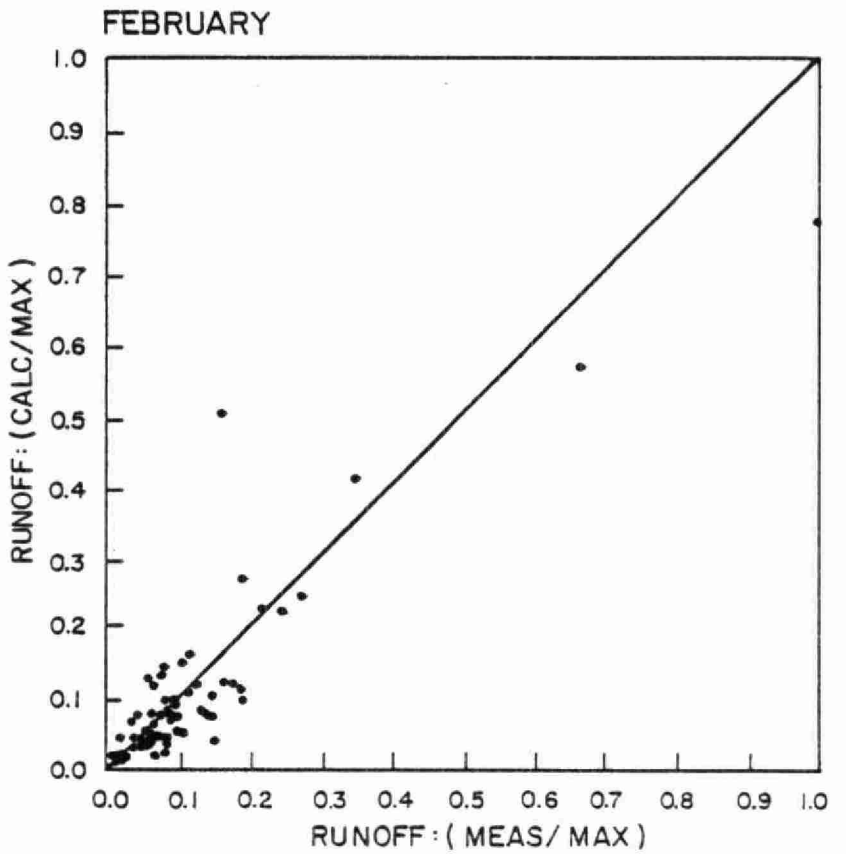
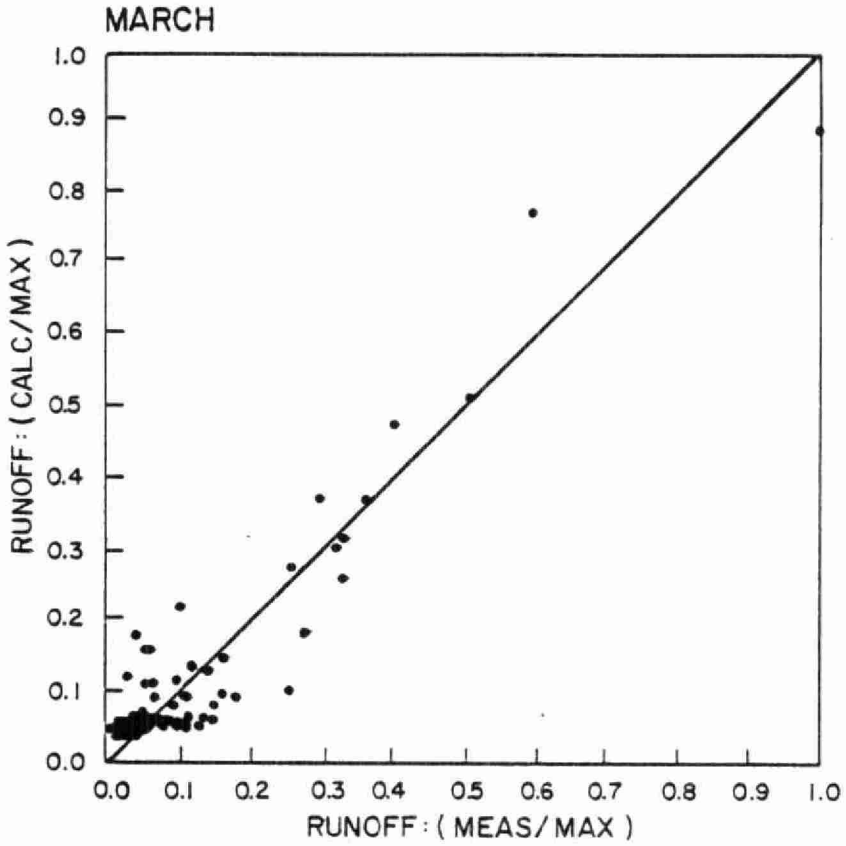


FIG. 2

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES



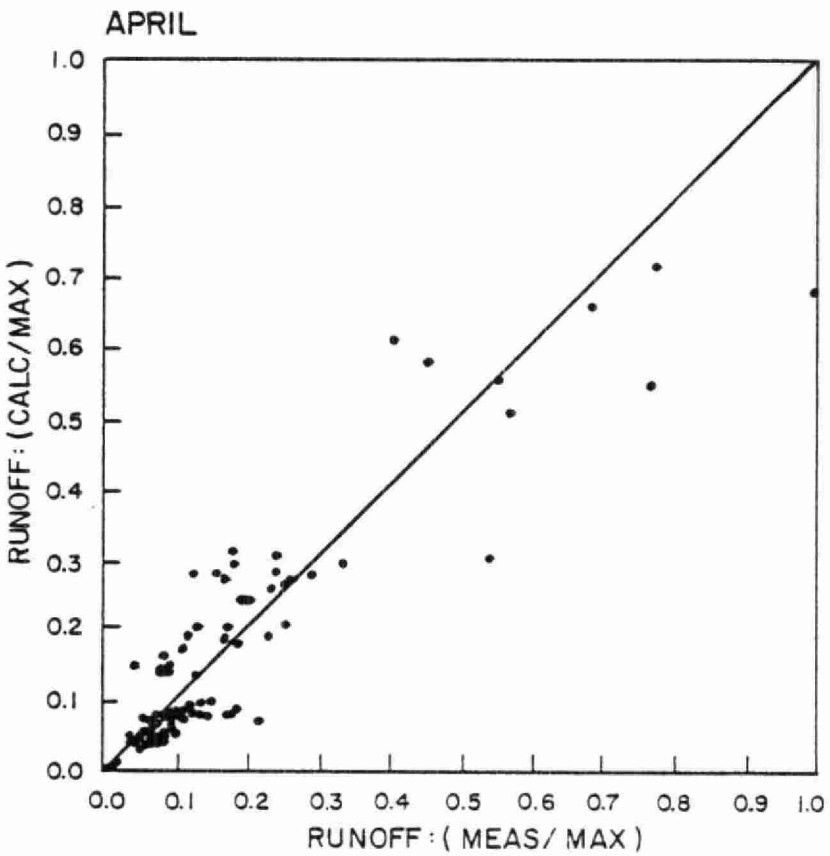
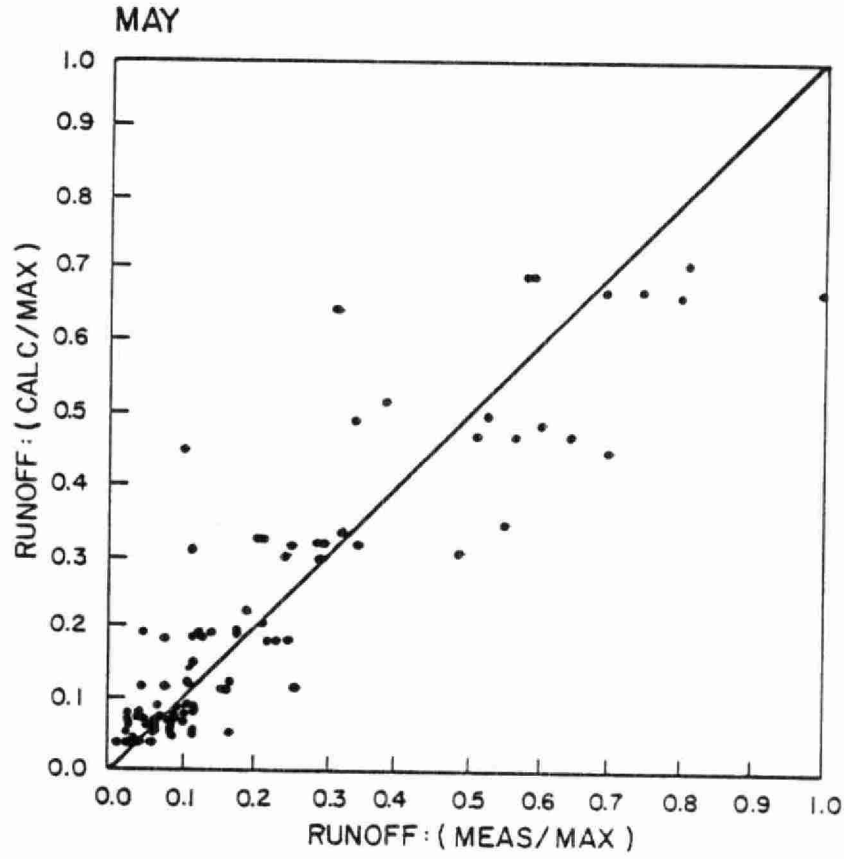


FIG. 3

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES



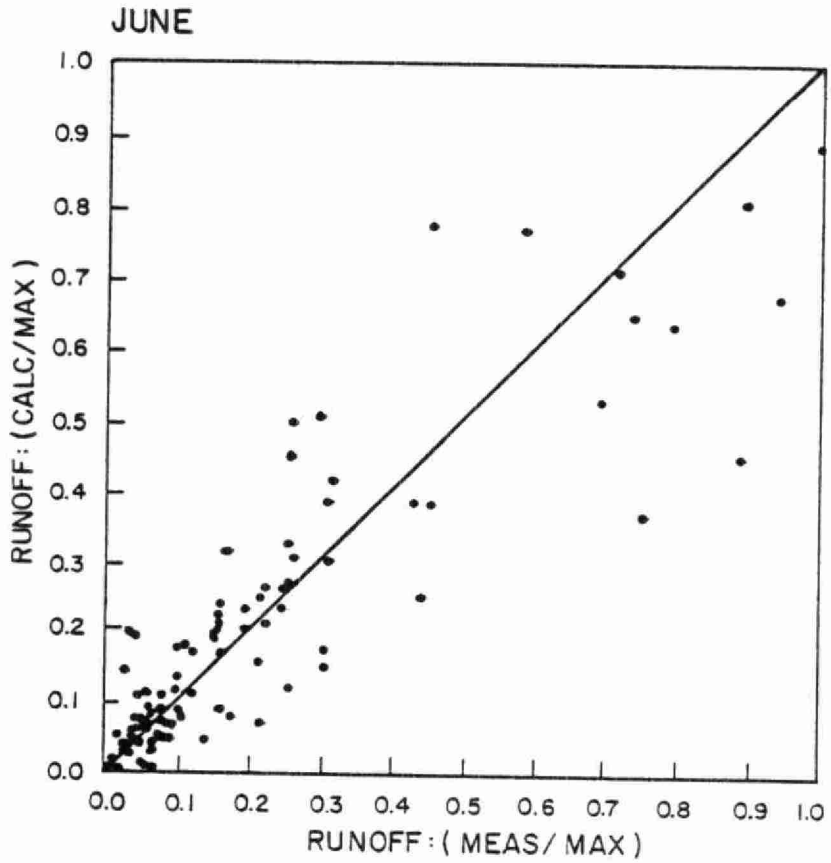
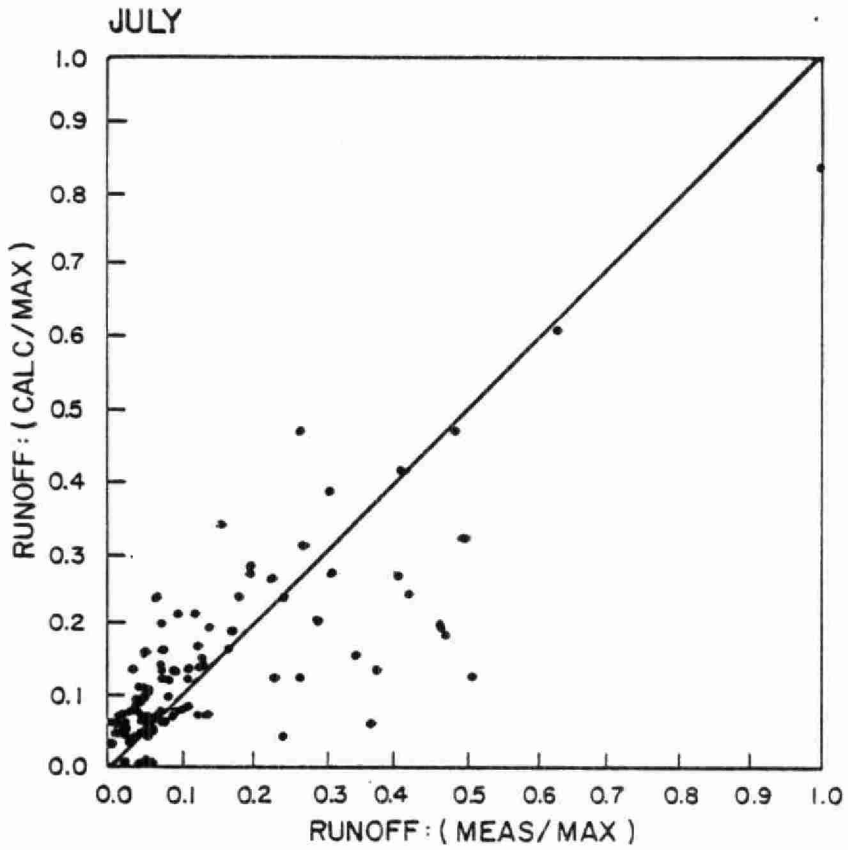


FIG. 4

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES



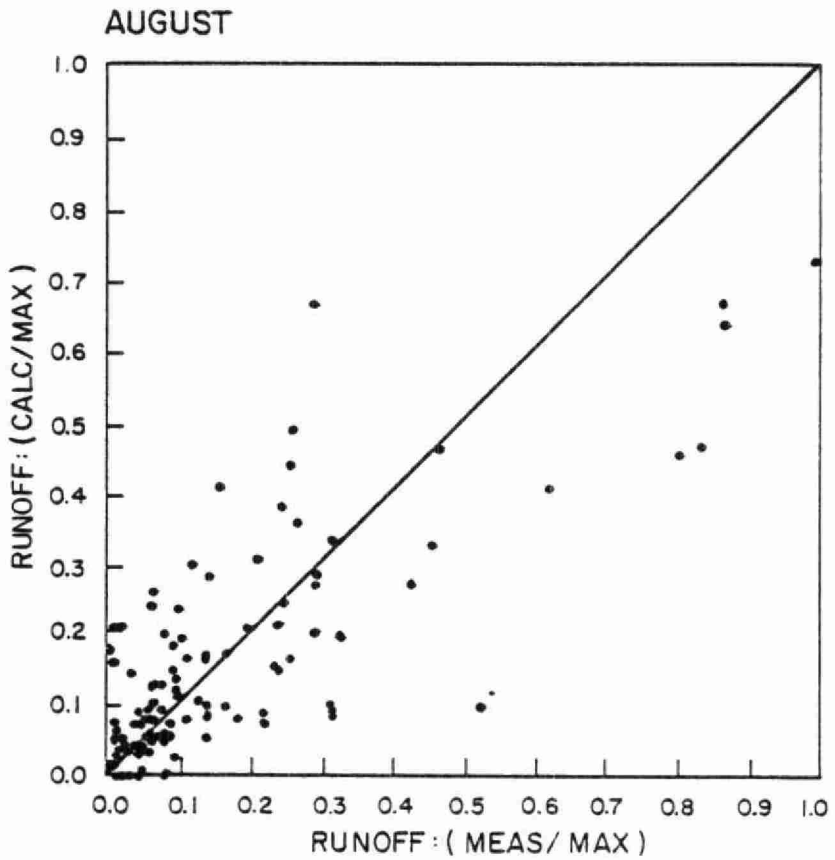
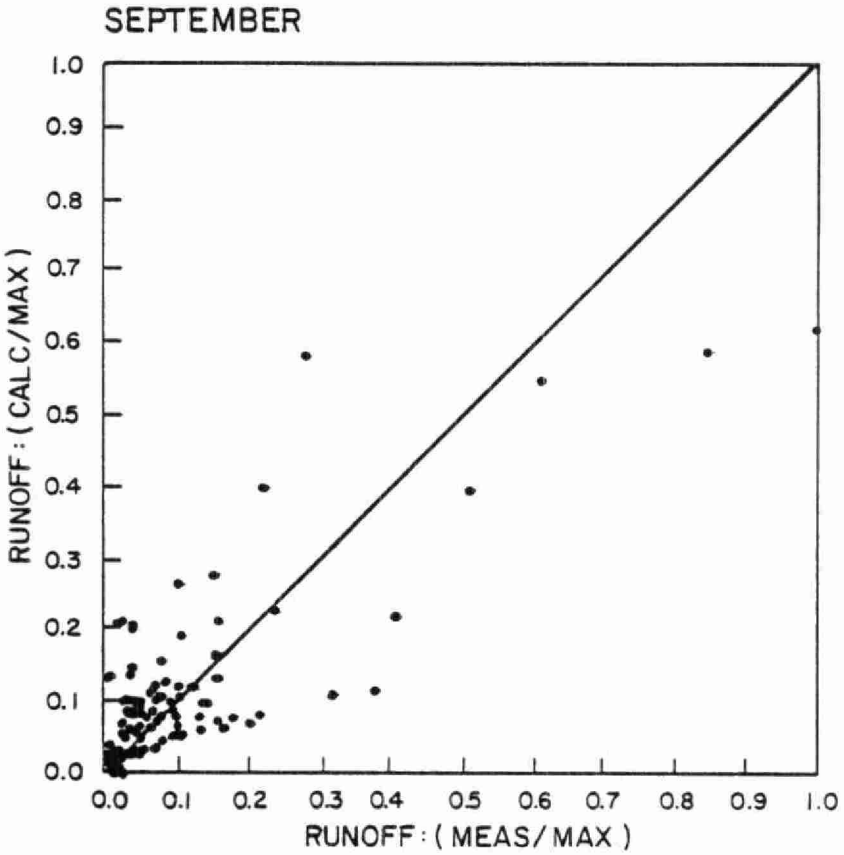


FIG. 5

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES



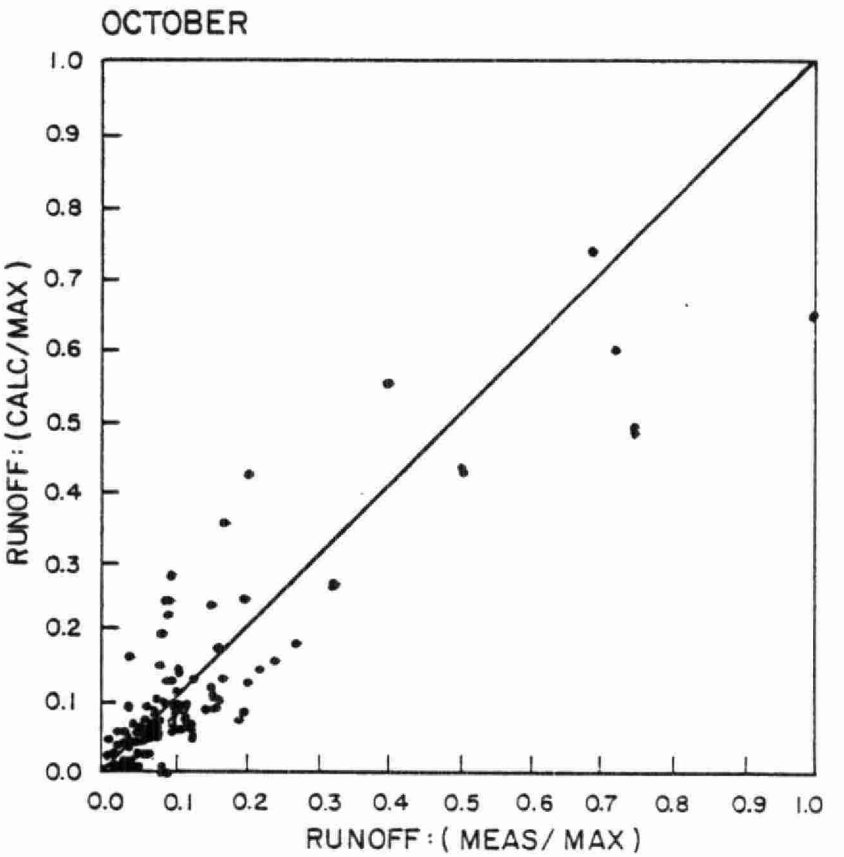
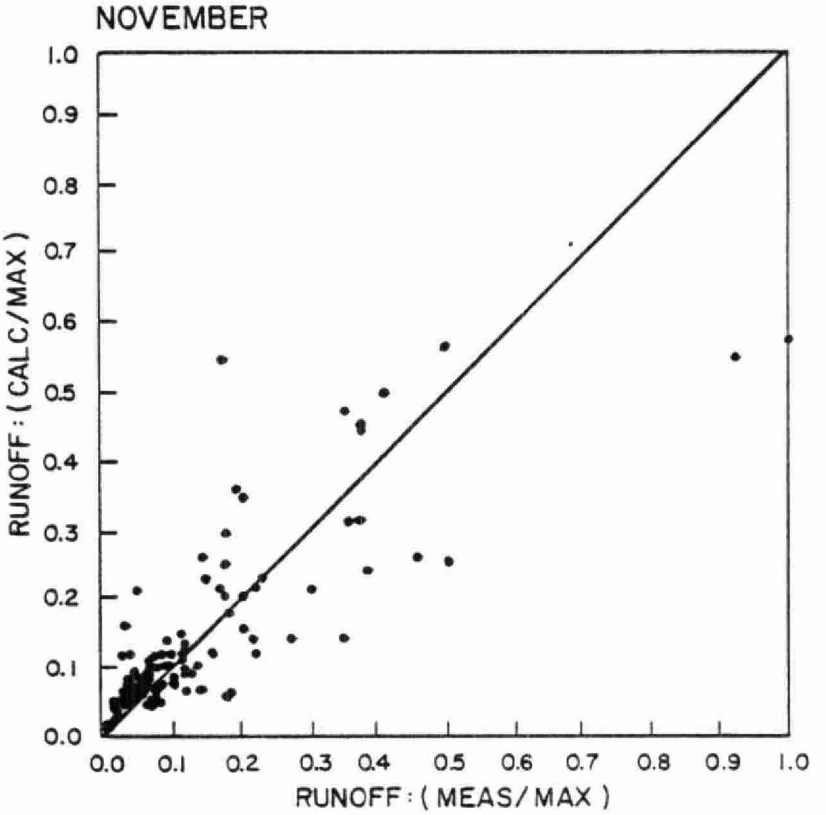


FIG. 6

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES



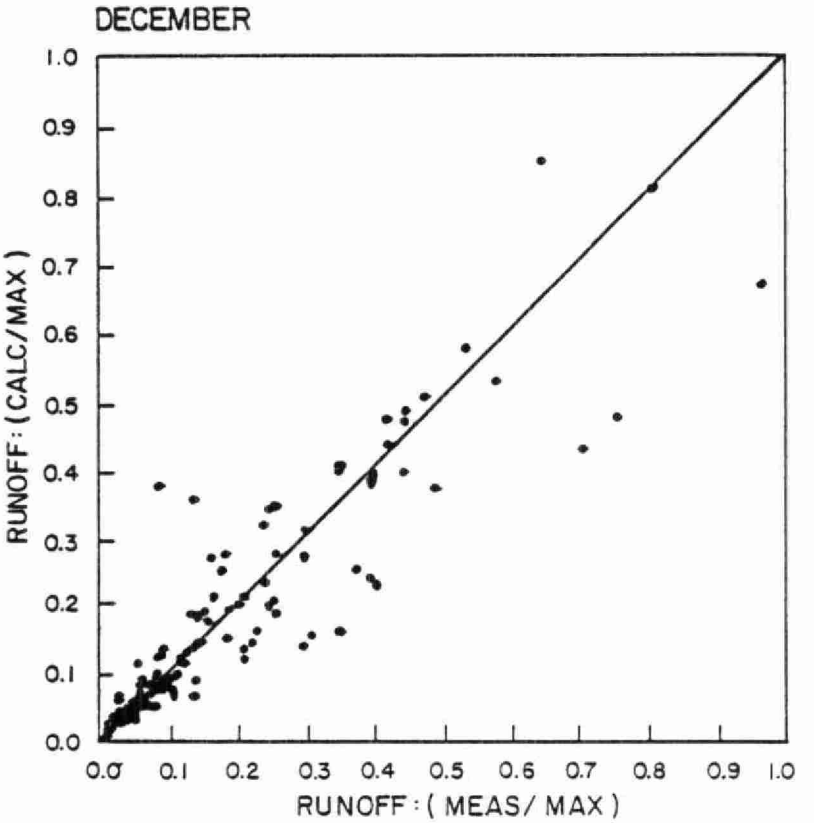


FIG. 7

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF SEQUENTIAL CORRELATION

ACRES

The coefficients which are listed in Table 2 respond as expected and are physically reasonable. In all months, one or more of the coefficients is zero. These zero coefficients occur when the particular independent variable by which the coefficient is multiplied is not significant for that particular month.

Table 2 lists values of the coefficient of determination (r^2) for each monthly relationship. Significant values of r^2 at the 90 and 95 percent confidence levels are also tabulated. These significant r^2 values are based on the assumption of 10 effective independent observations (see discussion of Section 3.3.2). The number of independent variables included in the relations varies from 2 to 4 and, hence, based on an assumption of 10 effective independent observations, the number of degrees of freedom varies from 5 to 7. The monthly relations for February, April, May, June, October, November and December are significant at the 95 percent level. The remaining months are all significant at the 90 percent level. The relations for July and August are only marginally acceptable at the 90 percent confidence level.

The scatter diagrams (Figures 2 to 7) indicate considerable variability between measured and calculated discharges. While reasonable relationships are indicated for most months, a poor predictive capability is indicated for July and August.

The derived equations represent the best possible relationships for statistically estimating the basin runoff in an ungauged catchment for a particular historic month.

3.4.2 - Ranked Correlations

In general, it is preferable to develop prediction equations for runoff based on the historic correspondence of runoff and climatic behavior. However, in cases where monthly basin precipitation estimates are not reliable and the objective is to reproduce or simulate the statistical behavior of basin runoff over a period of time, a ranked correlation analysis can sometimes give superior results. This problem of estimating basin precipitation is particularly acute where the nearest precipitation station is a long way from the basin. In this case, the statistical distribution of monthly rainfall at the gauge and over the basin may be similar but in any given month the two may differ widely.

To utilize the ranked approach, both precipitation and runoff are ranked from maximum to minimum within a specific basin. These two ranked vectors, along with the physiographic data, are then incorporated into the regression analysis.

During some months, particularly during spring runoff, the degree days of melt are more significant than precipitation. In such cases, the ranking procedure is based on degree days and runoff. When ranking the degree days, the precipitation is arranged to historically correspond with the ranked degree days. Similarly, if precipitation dominates, but degree days are still a contributing variable, the degree days are arranged to historically correspond with the ranked precipitation.

The analyses for the ranked approach resulted in the same general equations as were derived for the historic sequential correlations. The coefficients which were derived are tabulated in Table 3. The scatter diagrams relating measured and calculated runoff for each month are plotted in Figures 8 to 13.

There is considerably less scatter associated with this set of plots than the previous scatter plots of Figures 2 to 7. However, a direct comparison is somewhat deceptive. The scatter in the plots is a measure of both the basin-to-basin variability and the difference between the calculated and actual probability distributions of flow.

The scatter associated with Figures 8 to 13 is primarily due to the basin-to-basin variability. Only the data within each basin was ranked. When data for all 13 basins are lumped together, any bias is reduced because of the basin-to-basin variability. The coefficient of determination (r^2) is listed in Table 3 for each relation. However, because of the procedure adopted, the values cannot be interpreted in the normal way. Therefore, significant values of r^2 for 90 and 95 percent confidence levels are not tabulated. The relations are expected to have a similar significance to those presented in Table 2 for the historic sequential correlations.

3.5 - Summary

Physically acceptable equations have been developed for estimating natural monthly runoff in ungauged catchments of the

TABLE 3

COEFFICIENTS FOR RANKED CORRELATIONS

General Equation: (April to November)

$R = a_1 + A_B (a_2P + a_3) + A_L (a_4P + a_5) + a_6A_s$

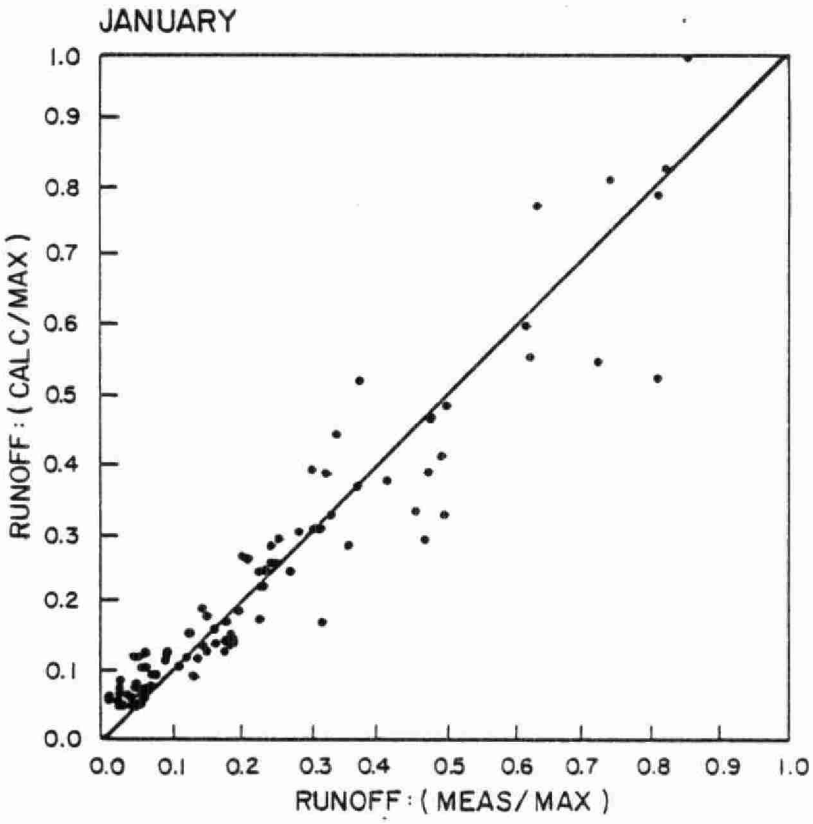
	Precipitation (m)	a_1	a_2	a_3	a_4	a_5	a_6	r^2*	SEE (m^3/s)*	$\bar{Q}$ (m^3/s)*
Apr	$(P_i + P_{i-1})/2$	-1.378	0.909	0.0	0.0	-0.249	0.192	0.92	4.30	13.75
May	$(P_i + P_{i-1})/2$	-0.587	0.374	0.0	0.0	0.247	-0.118	0.94	1.85	6.86
Jun	$(P_i + P_{i-1})/2$	-0.001	0.171	-0.004	0.0	0.118	-0.082	0.93	0.79	2.40
Jul	$(P_i + P_{i-1})/2$	0.318	0.107	-0.003	0.0	0.079	-0.072	0.78	0.89	1.49
Aug	$(P_i + P_{i-1})/2$	0.096	0.098	-0.004	0.0	0.043	-0.043	0.84	0.58	1.13
Sep	$(P_i + P_{i-1})/2$	0.019	0.166	-0.008	0.0	-0.025	-0.025	0.79	1.22	1.75
Oct	$(P_i + P_{i-1})/2$	0.194	0.278	-0.013	0.0	-0.049	0.0	0.79	1.83	2.94
Nov	$(P_i + P_{i-1})/2$	-0.036	0.394	-0.018	0.0	0.0	0.0	0.88	1.29	3.31

General Equation: (December to March)

$R = a_1 + a_2A_L + A_B (a_3 + P(a_4 + a_5D))$

	Precipitation (m)	Degree Days (0^oC)	a_1	a_2	a_3	a_4	a_5	r^2	SEE (m^3/s)	$\bar{Q}$ (m^3/s)
Dec	$(P_i + P_{i-1})/2$	$(Dmax_i + Dmax_{i-1})/2$	0.006	0.036	-0.009	0.213	0.00038	0.88	0.96	2.74
Jan	$(P_i + P_{i-1})/2$	$(Dmax_i + Dmax_{i-1})/2$	0.258	0.047	0.0	0.0	0.0022	0.90	0.38	1.33
Feb	$(P_i + P_{i-1})/2$	$(Dmin_i + Dmin_{i-1})/2$	0.144	0.040	0.001	0.0	0.049	0.85	0.84	1.40
Mar	$(P_i + I_{i-1})/2$	$Dmin_i$	1.176	-0.048	0.004	0.0	0.055	0.91	1.70	3.63

*r^2 is the coefficient of determination
*SEE (m^3/s) is the standard error of estimate
*$\bar{Q}$ (m^3/s) is the mean monthly discharge for all stations used in the analysis



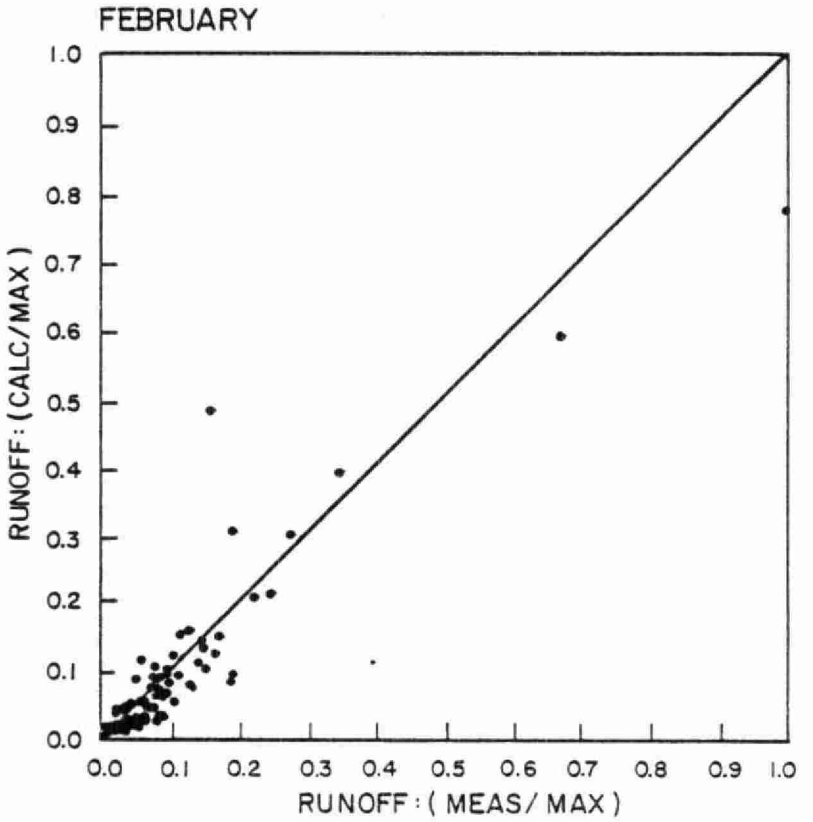
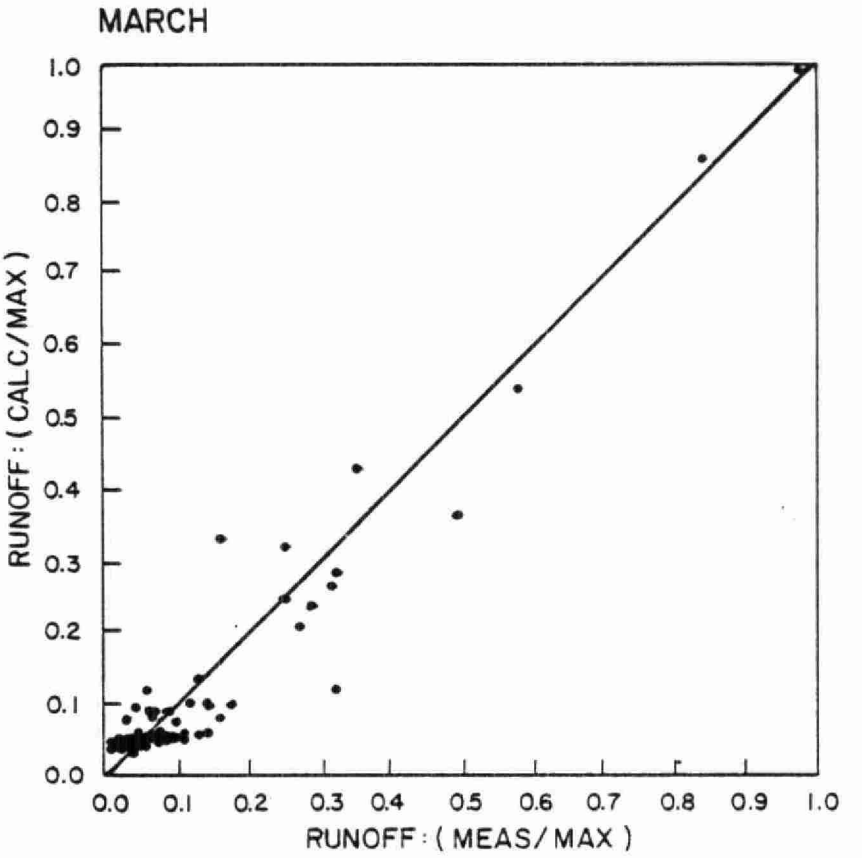


FIG. 8

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

ACRES



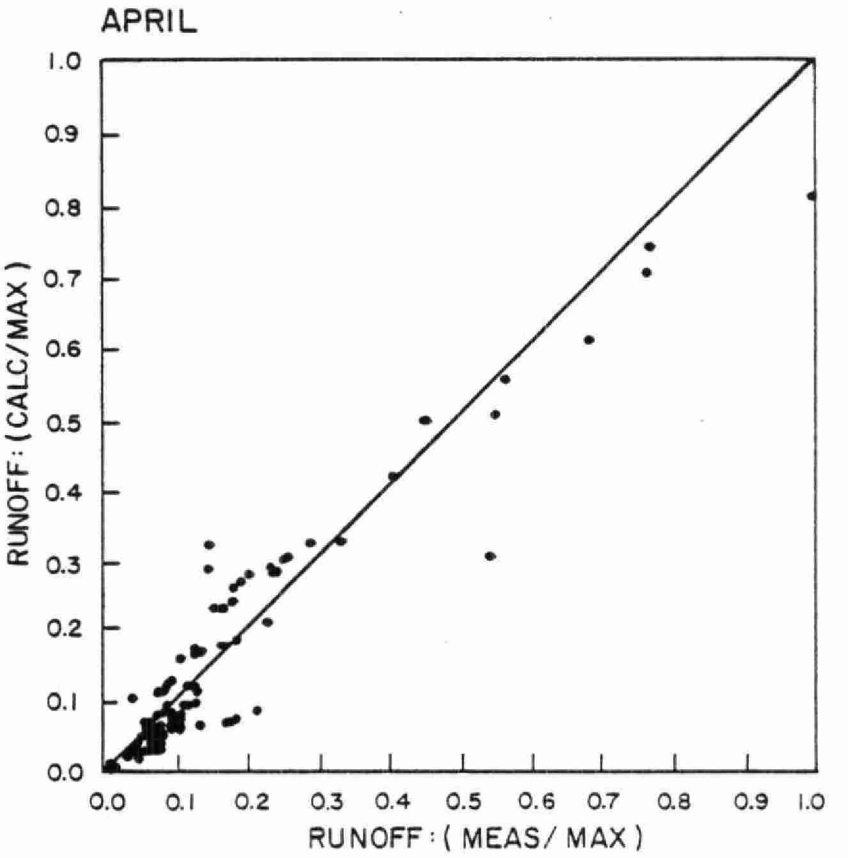
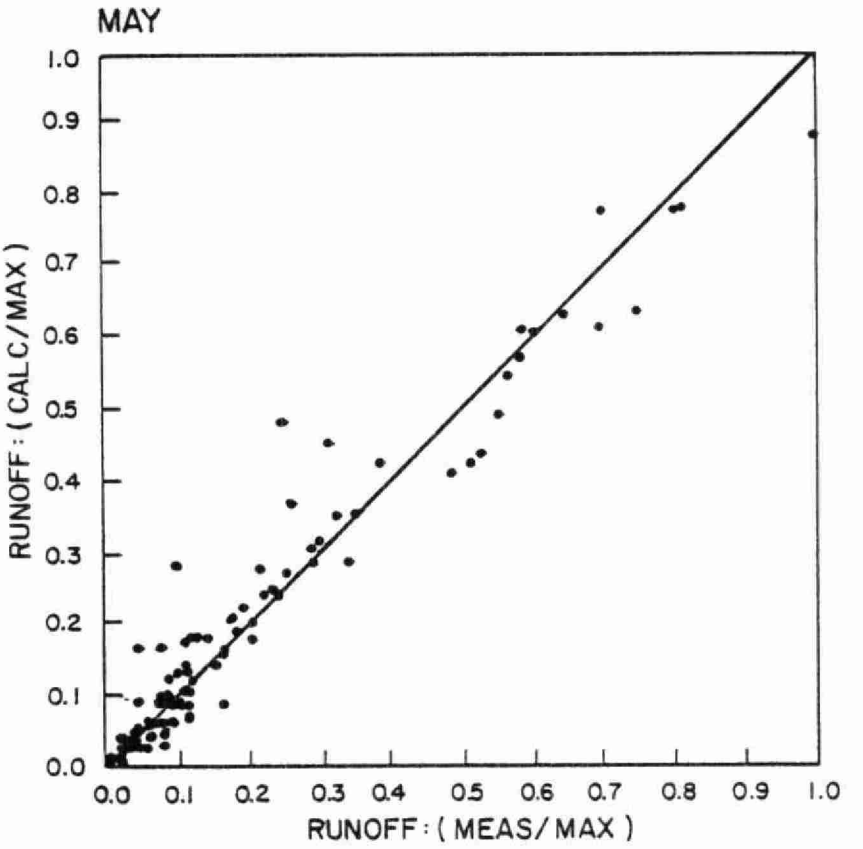


FIG. 9

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

ACRES



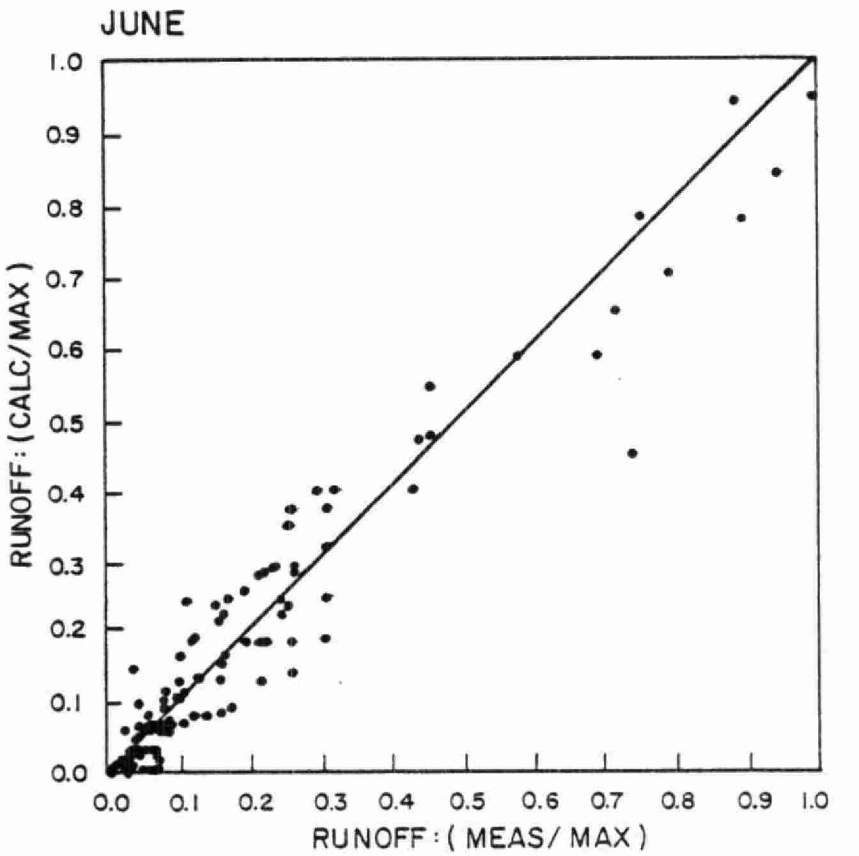
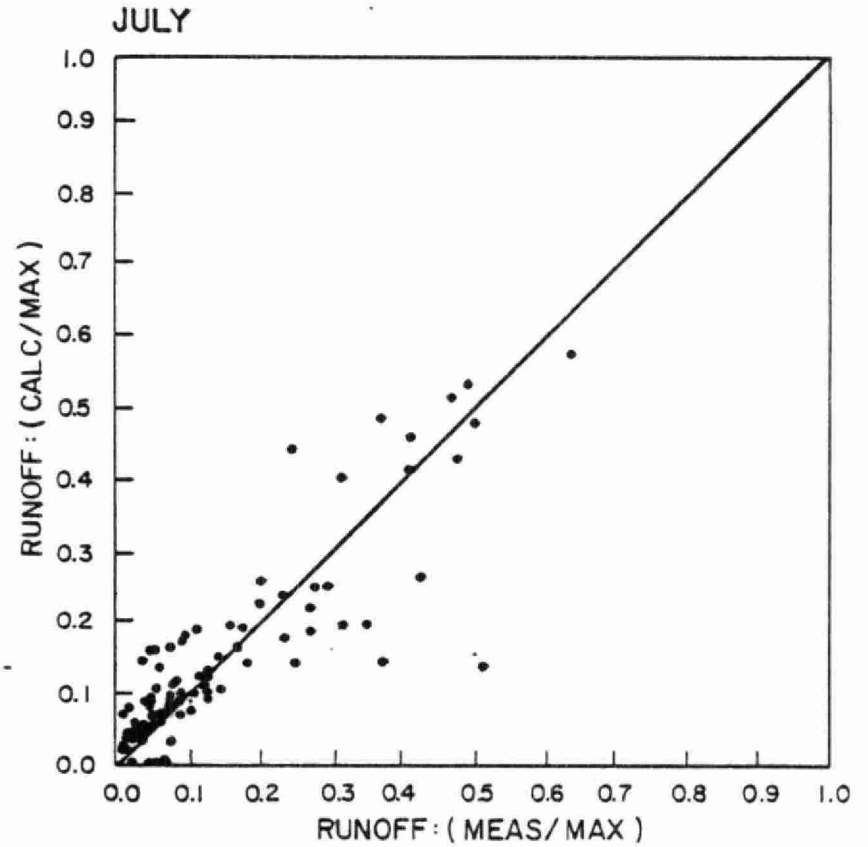


FIG. 10

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

ACRES



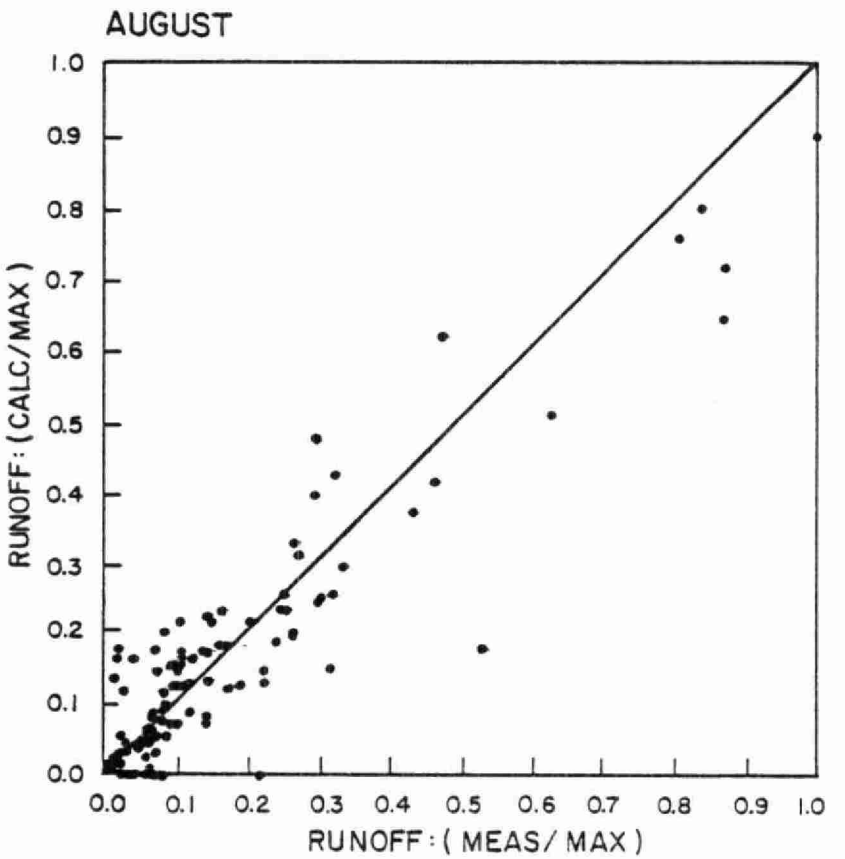


FIG. 11

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

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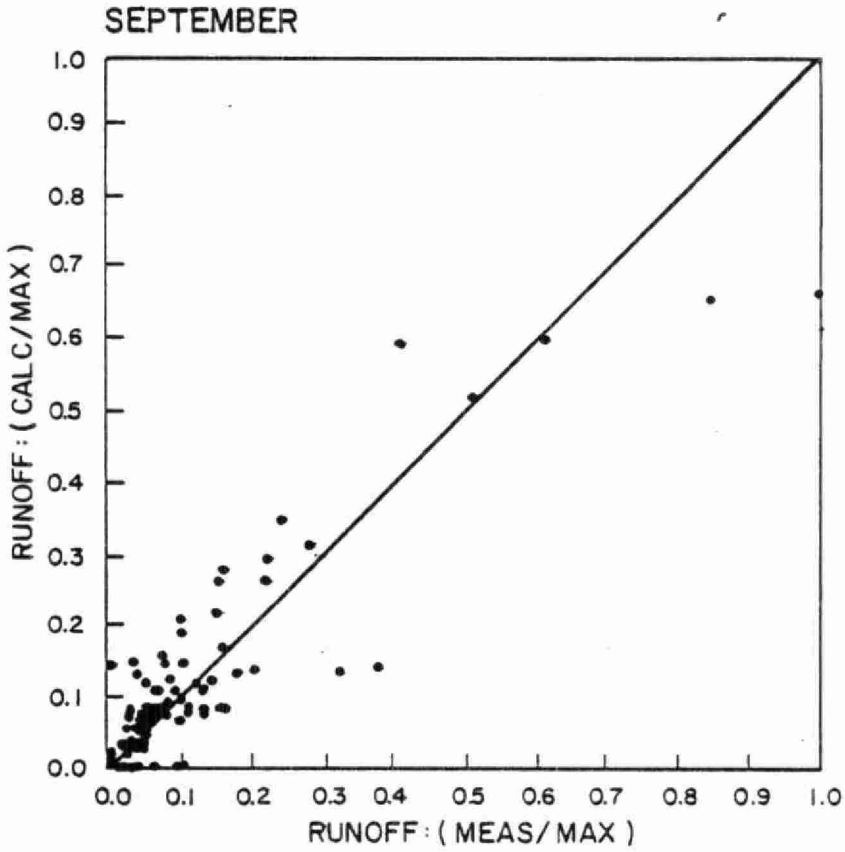

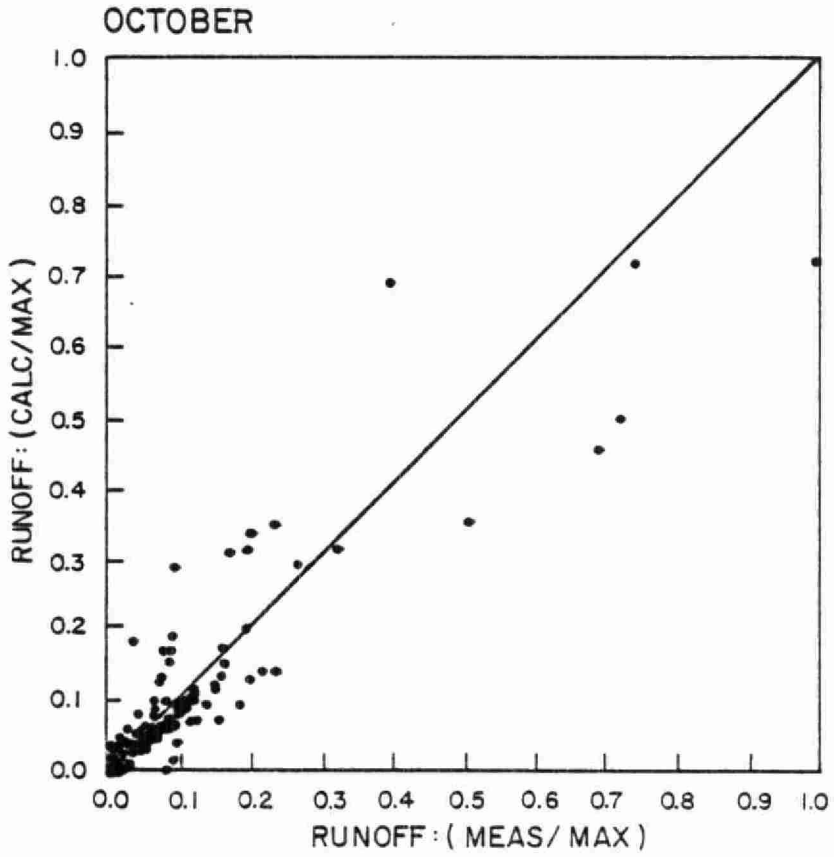

FIG. 12

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

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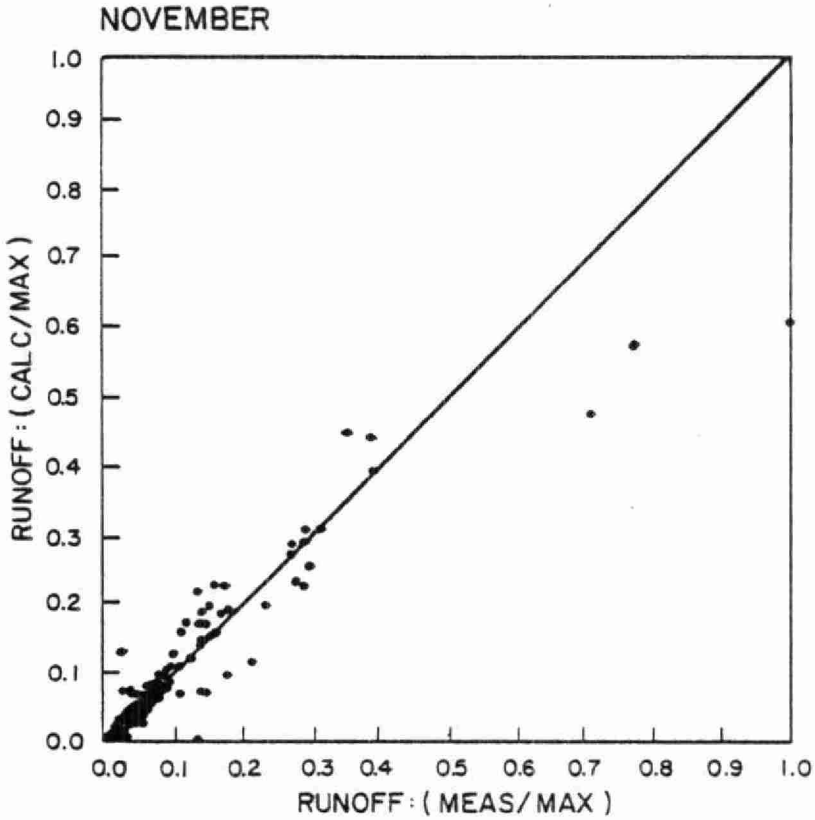

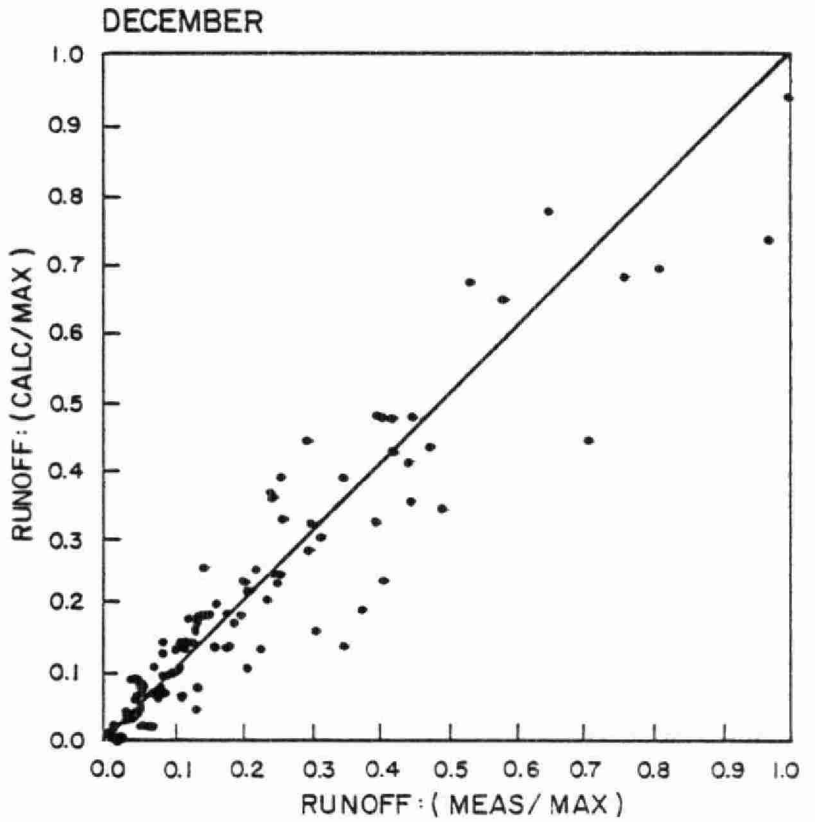

FIG. 13

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCATTER DIAGRAM OF RUNOFF RANKED CORRELATION

ACRES

Canadian Shield region of central Ontario. Although equations were developed for all 12 months, during July and August the relationships have limited predictive capability.

Two types of correlation analyses were performed. These are

- historic sequential
- ranked.

The relationships which were derived using historic sequential data are applicable to

- replicating or estimating runoff in a particular historic month

- reproducing the statistical behavior of monthly runoff (i.e., mean, standard deviation, skew of the monthly distribution). These estimates will also replicate data for a specific historic month.

The relationships which were derived using ranked data are applicable to

- reproducing the statistical behavior of runoff (i.e., mean, standard deviation, skew of the monthly distribution). These estimates will not replicate data for a specific historic month.

Initially it was not apparent whether the ranked or the historic sequential approach would best reproduce the statistical behavior of runoff. The test case of Section 5, which includes routing effects, indicates that the ranked approach is superior. The details of this test result are discussed in Section 5.4.

4 - FLOW PREDICTION MODEL

4 - FLOW PREDICTION MODEL

The development of a hydrologic model describing surface water movement depends on both the calculation of local runoff as described in Section 3 and on a procedure for calculating interbasin flow. The overall chain-of-lakes flow prediction model therefore contains two major components. It includes equations for predicting local runoff and it includes a routing submodel. The purpose of the routing submodel is to route estimates of local runoff through a chain of lakes which is subject to alternative types of regulation. A third component of the model incorporates calibration procedures so that the calculated runoffs and routed discharges can be adjusted to provide reliable replication of measured discharge at a basin outlet.

The overall model may be used for two distinct applications--for simulating historic monthly discharges and for simulating the statistical behavior of the basin in order that data extension can be performed. The primary difference between these two applications is the input data which is required and the calibration technique which is undertaken. A detailed discussion of the requirements for both is included later in this section.

The remainder of this section describes the following three components of the model

- natural runoff predictions
- lake routing
- calibration.

4.1 - Natural Runoff Predictions

Local runoff is calculated using the natural runoff prediction equations which were discussed in Section 3. The equations which are currently in the model are Equations 12 and 13. The coefficients a_1 to a_6 of these linear relations are read in as input data. These coefficients are listed in Tables 2 and 3 for the historic sequential and the ranked rainfall runoff correlations. If, in the future, the regression analyses of Section 3 are redone it is possible that equations with an alternative form, such as exponential or logorithmic will be derived. In this case it will be necessary to alter the Fortran coding for one subroutine of the model.

4.2 - Lake Routing

Interbasin flows are estimated by the use of the routing submodel presented in this subsection. Assumptions and simplifications of the routing submodel are discussed followed by a presentation of the subbasin discharge calculations. The subsection on subbasin discharge calculations includes a discussion of the two methods which are available within the model for estimating lake storage effects.

4.2.1 - Assumptions and Simplifications

The assumptions and simplifications which form the basis of the routing submodel are listed below.

- Channel routing and channel storage are neglected. This is based on the assumption that lake storage and lake routing predominate in regulating flows over a 1-month period.

- Lakes which do not have significant storage effects are not included in the routing procedure, but rather are handled implicitly through their inclusion in the runoff prediction equations.

- The model allows for one regulating lake per subbasin. This lake must be located at the downstream end of the subbasin.

- Outlet flows from lakes are modeled as either natural outlets or as regulated outlet structures.

4.2.2 - Subbasin Discharge Calculations

The subbasin discharge is calculated using basic continuity principles. The discharge from a subbasin is simply the sum of the following components.

- Local runoff estimated using the runoff prediction equations. When calculating the local runoff, the area of the regulated lake is excluded from both the area of basin and the area of lakes.

- Discharge entering the subbasin from one or more upstream subbasins.

- Net precipitation falling directly on the regulated lake. Net precipitation is the difference between monthly precipitation and monthly evaporation where evaporation is assumed to equal the long-term average for that month.

- Storage changes in the regulating lake.

If the subbasin outlet is selected such that no lake is at the outlet, the continuity equations reduce to local runoff estimates plus upstream inflows. Storage changes within each of the regulating lakes are estimated using either one of two techniques. The two techniques for estimating storage changes are outlined below.

(a) Regulation Subject to Rule Curve Operation

A rule curve for a particular lake is an operating policy which specifies an objective time series of lake elevations (normally a 1-yr cycle). Storage changes for rule curve operation assume that the lake is operated to match objective lake elevations. After accounting for inflows, water is discharged from the subbasin so as to ensure that each month-end lake level does not exceed the level specified by the rule curve. Where insufficient water supply exists, the end of month lake level is allowed to drop below the rule curve elevation. In this case the starting water level for the next month's storage calculation is the previous month's actual ending water level and not the rule curve level.

Under some circumstances historic monthly reservoir levels are available. These actual lake levels should be used instead of rule curve levels when they are available. The model is designed to accept these values as input, however, for actual operation of the model the historic lake levels are treated as if they were rule curve values. It is always preferable to use historic lake levels

if they are available instead of rule curves for historic simulations.

When using the model for statistical simulation purposes, rule curves are adequate, providing they reflect historic reservoir operation. Simple calculations can be made outside of the model to derive average "historic" rule curves rather than "objective" rule curves. The two do not always coincide.

(b) Regulation Subject to a Rating Curve

A rating curve for a particular lake is an elevation discharge relation for the lake outlet. Normally a rating curve will apply only to natural lakes but it will also apply to lakes with non-operated man-made structures. Rating curve storage estimates are made in the following manner.

- Inflow is assumed constant throughout the month and is divided into 10 equal segments.

- Each equal flow increment is routed through the lake, with the outflow during each time step governed by the lake elevation of that time step.

- The resulting 10 outlet discharges are averaged to give the mean monthly discharge.

A monthly subbasin discharge is produced by one of the above techniques in conjunction with the general continuity equation. This flow is then applied as an

inflow to the next immediate downstream subbasin. The procedure is repeated for each subbasin until monthly network discharges are calculated at all points.

Details of the discharge calculation procedure can be found in Appendix C.

4.3 - Calibration Procedures

The chain-of-lakes model consists of subbasin runoff calculations, followed by flow routing from subbasin to subbasin. The discharge at the downstream end of the drainage network can optionally be compared within the model to measured discharge records. Typically, differences will exist between the measured and calculated discharges.

Calibration is required to make the model basin specific. The following two calibation techniques have been incorporated into the model.

- Historic replication of a specific basin discharge record.

- Improvement of the runoff regression equations for a specific data record.

Each calibration technique is intended for a different purpose and consequently there are application limitations to each technique. The techniques and their limitations are discussed in the following subsections. Details of each are given in Appendix D.

4.3.1 - Historic Replication

Calibration using historic replication of a specific basin discharge record adjusts the subbasin runoff values on a month-by-month basis so that the total calculated basin discharge is equal to the measured basin discharge. This method is event specific and therefore is limited to application only for periods where historic discharge data is available. The subbasin runoff values are adjusted by prorating on the basis of subbasin runoff, as computed by the regression techniques. This approach is simply an extension and improvement of the common technique of prorating discharges based on subbasin area alone. Although this approach is physically realistic, it is not possible to judge its accuracy using the available data base. This calibration technique is intended for application on a basin which has a long historic record of measured discharges at a drainage basin outlet. The calibration will ensure that calculated and measured discharge match perfectly. In addition, it will be possible to estimate the origin of these flows from upstream subbasins based on prorating subbasin calculated runoffs (from regression equations) rather than simply from subbasin drainage areas.

To replicate the historic basin discharge, the following steps are followed by the model.

1 - The subbasin runoff is computed on a month-by-month basis for all subbasins. These values are summed to provide an overall basin runoff estimate.

2 - The subbasin runoffs are routed through the chain-of-lakes network and a calculated discharge at the

basin outlet is derived. For comparative purposes this initial calculated basin discharge is output along with the measured basin discharge.

3 - The total measured basin runoff is approximated by backrouting measured discharge with respect to changes in lake storage. Adjustments are also made for net lake evaporation.

4 - A ratio is computed by dividing the total measured basin runoff (Step 3) by the sum of the subbasin runoff (Step 1).

5 - The calculated runoff for each subbasin (Step 1) is then multiplied by the ratio which was computed in Step 4.

6 - The adjusted subbasin runoffs are routed through the drainage network.

7 - If additional iteration is necessary, Steps 3 to 6 are repeated.

The calculated basin discharge for each month will implicitly converge to the measured basin discharge. More than one iteration may be required because the total volume of stored water will normally vary from iteration to iteration.

4.3.2 - Improvement to Runoff Prediction Equations

Instead of replicating specific runoff on a month-by-month basis, an improvement to the runoff prediction

equations can be made within the model. This improvement to the runoff prediction equations has a broad basis for application and can be used for both historic simulation and for extension of discharge records beyond the period of available data.

Revised runoff prediction equations are derived for the overall basin based on actual measured basin discharge. The measured discharge is backrouted through the regulated lakes to remove the effect of lake storage. Monthly correlations are then made between these naturalized flow records and the appropriate climatologic data. The form of these equations is identical to Equations 14 and 15 of Section 3.4. The result is a set of 12 revised runoff prediction equations which are calibrated for the specific basin under study. These revised equations are then used to calculate an overall basin runoff on a month-by-month basis. In the same manner as was done for Section 4.3.1, ratios are calculated between revised basin runoff and initial basin runoff. These ratios are then multiplied by the initial individual subbasin runoff estimates. A detailed description of this calibration technique is presented in Appendix D. The general methodology is as follows.

1 - For the entire simulation period, subbasin runoffs are calculated by using the runoff prediction equations without any adjustment factor. These values are summed to provide an overall basin runoff estimate.

2 - For the entire simulation period, the subbasin runoffs are routed through the drainage network and calculated discharges are derived for the basin

outlet. For comparative purposes these calculated basin discharges are output along with the measured basin discharge.

3 - The total measured basin runoff is approximated by backrouting the measured discharge with respect to changes in lake storage. Adjustments are also made for net lake evaporation.

4 - For each of the 12 months, linear equations are developed which describe the total measured basin runoff in terms of the climatologic data. The equations are used only to calculate the total basin runoff.

5 - On a month-by-month basis, the total basin runoff is calculated by using the revised regression equations, as developed in Step 4.

6 - On a month-by-month basis, adjustment ratios are calculated by dividing the initial predicted basin runoff (Step 1) into the adjusted basin runoff (Step 5).

7 - The individual subbasin runoffs (Step 1) are then multiplied by the appropriate ratio as determined in Step 6.

8 - For the entire simulation period, the subbasin runoffs are routed through the drainage network.

9 - If additional iteration is necessary, Steps 3 to 8 are repeated.

The total basin average monthly discharge, as computed in the above calibration technique, will implicitly converge toward the corresponding average for measured discharge. More than one iteration may be required because the total volume of stored water will normally vary from iteration to iteration. This variation in volume of stored water from iteration to iteration will only occur for the rating curve storage assumptions or when lake levels do not reach rule curve levels. If all lakes are operated to rule curve and all lakes achieve this objective level then only one iteration will be required for perfect closure.

The results of the calibration can be used for subsequent data extension runs of the model. The results of the linear runoff equations (Step 4) can be read into the model as input data. Steps 1, 2 and 5 to 8 are then repeated within the model to produce basin specific subbasin and total basin discharge values.

4.4 - Model Application

This section presents an overview of necessary steps and data requirements for running the flow prediction model. A description of output options is included.

4.4.1 - Required Input Data

Details of the data input requirements are given in Appendix E.

Prior to collection of pertinent data it is necessary to delineate the basin and subdivide it into the desired subbasins. Guidelines for this task are as follows.

- Any stream network to be simulated should preferably incorporate the drainage area above a streamflow gauge. It is desirable, although not necessary, to include a known gauge as the downstream node of the network in order to take advantage of the calibration procedures within the model. If additional streamflow gauges exist within the network, then the drainage area should be divided into separate networks for each gauge.

- Individual subbasins should preferably not exceed about 750 km^2. Use of larger basins requires using the runoff prediction equations beyond the range for which they were developed.

- Subbasin nodes should be located at the outlet of all regulated lakes, or of all lakes which have significant natural regulation.

- Subbasin nodes should also be located at any point where a flow prediction is required.

- The subbasins must be assigned a nodal number. Any numbering system can be assigned because the model does not make assumptions on the numbering hierarchy. The interconnection of nodes is defined through the input data.

The required data for each of the three components of the model is discussed below.

(a) Natural Runoff Predictions

- Climatologic data such as precipitation and degree days above 0°C for each subbasin based on the nearest or most appropriate station.

- Evaporation data for each month.

- Physiographic data such as areas of subbasins, lakes and swamps.

- Coefficients of the runoff prediction equations (a_1 to a_6) for either the historic sequential or ranked rainfall/runoff correlations.

(b) Lake Routing

- Reservoir rule curves (either objective or historic).

- Historic month-end lake elevations.

- Outlet descriptions for natural lake outlets or nonoperated lake structure outlets.

(c) Calibration

- Historic monthly discharges at the outlet to the overall basin.

In addition there are numerous flags and codes that must be input to control the selection of computational options. Details of these codes and flags can be found in Appendix E.

4.4.2 - Output Selection

There are three basic output options available within the model. They are described briefly below.

(a) Detailed Month-by-Month Output

This output lists details for all subbasins, one page for each month of simulation. Details of input data, lake level changes and calculated discharge are provided for each step of the computations. This output can be used for assessing the relative significance of various components of the model or of particular subbasins within the network.

(b) Discharge Summary

This output provides a discharge summary for the simulation, one page for each subbasin. In addition, for calibration runs, a summary table is provided which lists measured and calculated discharge at the network outlet. This summary is provided for each iteration of the calibration procedure (normally 2 or 3 iterations).

(c) Lake Level Summary

This output provides a lake level summary for all months of simulation, one page for each subbasin (i.e., each major lake). This output provides information on lake level variations and indicates whether or not objective rule curve levels were achieved.

There are two other forms of output which are always produced and which are intended for use as input data for future computations. These are

- output in the correct format to be read by the existing Serpent River water quality model

- output in the correct format to be read by this chain-of-lakes flow prediction model as an input to a future downstream network.

Both of these output forms are sent to separate computer output units. Details of the output units can be found in Appendix E and example output can be found in Tables F-8 and F-9 of Appendix F.

5 - TEST RESULTS

5 - TEST RESULTS

The results of calibrating and running the model are presented in this section in order to verify correct operation and to demonstrate an application of the model.

The South Branch Muskoka River was selected for testing the chain-of-lakes model. This basin was selected because of Acres' familiarity with the region, and because the required data was readily available.

A description of the basin and its operation, including data availability and limitations, is presented in this section.

The test results are presented for the following two cases

- month-by-month historical replication
- statistical simulation.

A discussion of the accuracy and acceptability of the results for each test is included in Sections 5.3 and 5.4. Sections 5.1 and 5.2 are a description of the South Branch Muskoka River and the lake levels used in the test runs.

5.1 - Description of the South Branch Muskoka River

The South Branch Muskoka River is a subbasin of the overall Muskoka drainage basin which drains an area of 4,770 km^2, stretching from Algonquin Provincial Park to the outlet of Lake Muskoka near Georgian Bay. The south branch drains an area of approximately 1,500 km^2. This study only used the drainage area of 1,390 km^2, located upstream from the WSC streamflow gauge located at Baysville (2EB008).

The South Branch Muskoka River is characterized by six major lakes subject to regulation policy, as well as several smaller lakes regulated by nonoperative structures. Following the guidelines of Section 4.1.1 the overall network was divided into six subbasins. The outlet of each of the six major lakes represents the outlet of each of the six subbasins. Figure 14 is a schematic of the network.

The water levels of all six lakes are subject to rule curve operation. The water levels of Lake of Bays and of Lake Kawagama are monitored daily. Adjustments to log settings are made as necessary. The water levels of the remaining four lakes are not monitored on a daily basis. As well, the log settings are only changed a few times a year.

Daily water levels are available for Lake Kawagama dating from 1975. For Lake of Bays, data for the period dating from 1973 is presently on hand.

Discharge records for the streamflow gauge at Baysville date from 1942; however, because of the limitations of the other data bases, the period from 1970 to 1981 was selected. The discharge records are presented in Table 4.

Meteorologic data for Huntsville (1970 to 1981) was selected as representative of the South Branch Muskoka River. The data are presented in Table B-3 of Appendix B. Occasionally, data for Huntsville is missing. For the missing months, meteorological data for Dwight is used as a substitute for the missing Huntsville data.

The physiographic data were taken from 1:50 000-topographical maps and from records supplied by the Ontario Ministry of Natural Resources.

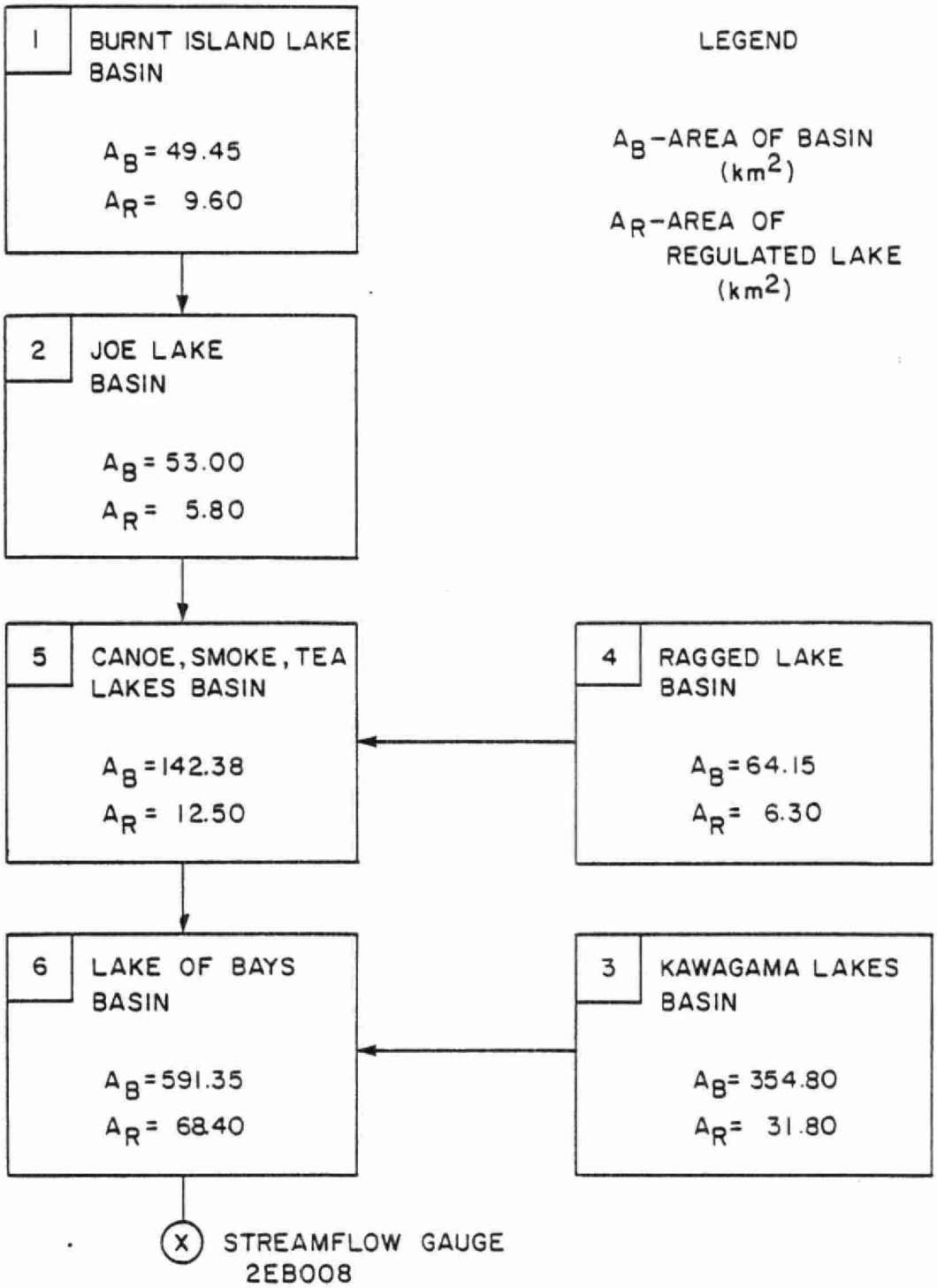

FIG. 14

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCHEMATIC OF THE SOUTH BRANCH OF THE MUSKOKA RIVER

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TABLE 4 HISTORICAL DISCHARGE RECORDS AT BAYSVILLE

Discharge in Cubic Meters per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1970	20.2	22.2	22.3	28.3	43.6	13.8	49.9	20.4	11.2	30.9	21.3	25.6	25.9
1971	19.7	27.3	36.1	47.5	33.6	11.1	5.2	5.8	13.2	7.6	8.4	10.4	18.7
1972	19.2	24.0	31.6	40.1	64.3	18.5	26.1	31.9	16.0	24.7	31.9	21.8	29.2
1973	29.5	40.9	57.3	58.8	34.7	31.9	17.6	16.5	15.9	16.8	10.7	25.5	29.6
1974	25.9	33.3	40.6	57.1	64.7	19.7	7.6	6.8	12.3	26.1	28.4	22.5	28.7
1975	20.3	23.1	40.1	35.5	31.5	4.6	3.4	5.1	13.8	20.1	10.4	32.0	20.0
1976	25.0	27.6	50.5	69.1	24.0	8.5	18.6	6.3	6.2	11.8	8.2	12.9	22.4
1977	15.4	13.8	41.5	38.7	13.9	4.0	3.0	3.3	14.4	33.7	24.1	27.5	19.5
1978	29.7	19.5	27.7	25.1	53.4	11.3	4.0	6.3	19.7	25.6	14.7	21.4	21.6
1979	21.5	30.7	50.1	57.4	44.7	15.8	5.1	9.5	22.1	28.3	43.1	40.1	30.6
1980	30.2	25.1	23.0	78.5	20.6	22.5	17.0	22.8	24.3	33.9	30.3	24.3	29.3
1981	20.9	37.1	52.6	31.8	22.3	13.6	5.2	4.0	61.8	37.5	14.6	16.7	26.4

5.2 - Lake Level Estimates

When calibrating and running the model, four alternatives are generally available for accounting for changes in lake elevations. One method utilizes rating curves. It is not discussed here since it is not applicable to the South Branch Muskoka River. The three remaining methods are

- rule curves
- historic rule curves based on average recorded lake levels
- historic lake levels.

An examination of historic lake levels indicate that the major lakes (Lake Kawagama and Lake of Bays) were not operated exactly to rule curve. Consequently, average historic lake levels were used to derive average historic rule curves. When using the model for statistical simulation, these average historic rule curves for Lake Kawagama and Lake of Bays were used in place of the objective rule curves. The objective rule curves were used for the four remaining regulated lakes. However, when calibrating and running the model on a month-by-month basis, historic lake levels were used for Lake Kawagama and Lake of Bays. These levels were used in order to take advantage of the best available data.

5.3 - Historic Replication

The model was run for the period 1975 to 1980. The historic replication calibration procedure was selected for use in the model to ensure that measured and calculated discharge at the downstream node of the basin matched perfectly. Table 5 lists the basin runoff provided initially by the prediction equations (sum of all six subbasins) and the final basin runoff after calibration.

TABLE 5 COMPARISON OF CALIBRATED AND UNCALIBRATED BASIN RUNOFF FOR HISTORIC REPLICATION OF THE SOUTH BRANCH MUSKOKA RIVER

Discharge in Cubic Meters per Second

YEAR	CALIBRATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	NO	10.4	20.4	21.0	44.1	46.7	16.8	11.1	8.0	7.6	9.7	19.0	36.9
	YES	14.2	11.4	18.9	60.7	41.7	10.9	6.6	4.1	4.6	8.4	12.1	30.3
1976	NO	11.2	7.5	133.7	49.5	45.7	19.2	10.3	6.4	5.9	12.5	24.7	19.0
	YES	13.5	9.6	51.7	93.0	26.0	11.9	20.0	5.1	-3.4	2.1	2.8	9.9
1977	NO	9.4	7.2	35.3	42.1	45.6	15.1	8.8	8.6	9.2	18.4	32.1	15.8
	YES	2.6	5.0	43.3	68.3	17.6	6.6	5.3	3.5	4.1	23.0	26.1	23.0
1978	NO	9.4	8.3	11.4	32.1	46.0	18.3	12.1	11.3	11.7	18.4	20.2	13.3
	YES	14.2	8.7	10.8	55.9	69.3	14.4	6.4	4.5	6.6	17.0	16.7	18.9
1979	NO	11.1	7.6	45.4	67.3	47.6	21.2	14.4	8.0	6.6	19.2	21.7	22.4
	YES	13.5	9.7	45.5	91.4	41.9	10.2	15.7	10.8	5.4	22.8	43.1	33.5
1980	NO	9.2	6.6	62.2	56.7	47.8	23.4	17.7	13.6	11.5	21.5	14.3	18.1
	YES	23.7	9.2	24.4	99.9	22.9	26.8	20.4	14.3	16.9	22.0	31.8	16.0

The results of the simulation illustrate that the model can be run to produce historic discharges at the downstream node. However, the initial runoff prediction may have to be adjusted considerably to produce the desired result (see Table 5). The magnitude of the adjustments may be attributed to the following causes:

- the runoff prediction equations are not basin specific

- climatological data from Huntsville may not adequately represent precipition and temperature in the basin of the south branch of the Muskoka River on a month-by-month basis

- there may be errors in the historic lake levels recorded for Lake Kawagama and Lake of Bays

- the rule curves may not always represent actual lake levels in each of the four smaller regulated lakes.

Detailed output for this test run is presented in Appendix F, including input data files and output listings.

5.4 - Statistical Simulation

Two separate statistical simulation test runs were made. The runs were made using both the historic sequential and ranked rainfall/runoff correlations. In both cases the model was run for the period 1970 to 1981 using historic rule curves for Lake Kawagama and Lake of Bays. The calibration procedure of Section 4.3.2 was applied to improve the runoff prediction equations and make them basin specific.

Table 6 is a presentation of the results using the ranked runoff prediction equations. The measured basin discharges and the calculated basin discharges are listed in the table. Since the ranked approach was used, each measured discharge is paired with the calculated discharge of similar rank. At the bottom of the table the means, standard deviations and coefficients of skew are listed for both the measured and calculated data sets. The calculated and measured means are equal as required by the calibration. The standard deviations are virtually identical in all months while the coefficients of skew are not at all similar. However, 12 data points are not sufficient to adequately evaluate skewness. The standard error between ranked measured and ranked calculated discharge is also given in Table 6.

An identical run was made using the historic sequential runoff prediction equations. The calculated and measured means are again equal. Table 7 lists the calculated standard deviations. In addition, Table 7 lists the measured standard deviations and the standard deviations which were calculated using the ranked runoff prediction equations.

The results which are presented in Table 7 verify that the ranked approach produces better statistical results than the historic sequential approach. Therefore, it can be concluded that the ranked approach is probably better suited than the historic sequential approach for extending discharge data beyond the period of available data. However, this conclusion is valid provided that only the statistical behavior of runoff is required and that reproduction of specific historic monthly discharge is not required. If a reproduction of historic monthly discharge records is required, then only the historic sequential approach can be used for data extensions.

TABLE 6 COMPARISON OF MEASURED AND CALCULATED DISCHARGE AT BAYSVILLE USING THE RANKED CORRELATION TECHNIQUE

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1	CALC	17.2	22.2	32.0	46.6	55.0	17.4	37.5	18.4	11.1	26.4	16.2	28.7	27.4
	MEAS	15.4	13.8	27.7	47.5	64.3	19.7	49.9	20.4	12.3	28.3	14.6	32.0	28.8
2	CALC	21.9	27.1	31.8	26.3	17.2	10.2	6.0	6.3	1.6	6.7	15.4	28.6	16.6
	MEAS	20.9	30.7	23.0	28.3	13.9	8.5	5.1	5.8	11.2	7.6	8.1	27.5	15.9
3	CALC	31.2	24.6	41.6	46.4	44.6	14.2	19.3	18.1	15.9	25.2	15.9	20.4	26.5
	MEAS	30.2	27.3	50.1	40.1	34.7	18.5	17.6	16.5	13.8	24.7	10.7	21.4	25.5
4	CALC	28.2	37.5	57.3	51.9	50.6	35.8	33.2	0.0	0.0	13.6	17.5	25.3	29.2
	MEAS	29.5	37.1	52.6	57.4	53.1	31.9	26.1	4.0	6.2	11.8	21.3	25.5	29.7
5	CALC	29.9	22.8	32.4	68.5	62.4	11.2	0.0	6.2	26.6	32.2	19.3	23.5	27.9
	MEAS	29.7	24.0	31.6	69.1	64.7	11.3	3.0	5.1	22.1	33.7	30.3	24.3	29.1
6	CALC	24.1	36.7	33.8	41.7	31.2	8.6	6.7	8.8	17.3	18.1	17.1	41.0	23.7
	MEAS	25.0	33.3	36.1	38.7	31.5	4.6	5.2	6.3	14.4	16.8	14.7	40.1	22.2
7	CALC	23.2	25.4	61.8	51.5	19.8	12.6	2.1	0.0	21.3	25.3	18.8	18.2	23.3
	MEAS	21.5	27.6	57.3	57.1	24.0	13.6	3.1	3.3	16.0	25.6	24.1	16.7	24.2
8	CALC	20.4	22.6	35.1	37.4	17.3	7.2	4.5	10.7	23.7	26.2	22.4	9.6	19.7
	MEAS	20.3	23.1	40.6	31.8	20.6	4.0	4.0	6.8	19.7	26.1	31.9	10.4	19.9
9	CALC	18.3	22.8	29.9	20.2	19.7	11.2	12.3	17.9	26.9	20.3	15.6	15.0	19.2
	MEAS	19.2	25.1	22.3	25.1	22.3	11.1	17.0	9.5	24.3	20.1	10.4	12.9	18.3
10	CALC	24.7	22.3	40.0	38.8	44.8	13.1	6.3	8.8	14.3	33.0	19.2	26.7	24.3
	MEAS	25.9	19.5	41.5	35.5	43.6	13.8	5.2	6.3	13.2	33.9	28.4	25.6	24.4
11	CALC	20.1	22.6	42.7	70.7	43.5	19.8	26.7	18.6	21.0	30.2	14.2	21.9	29.3
	MEAS	20.2	22.2	50.5	78.5	33.6	22.5	18.6	22.8	15.9	30.9	8.2	22.5	28.9
12	CALC	18.4	38.0	35.1	67.9	45.1	13.9	8.2	25.2	51.1	39.6	54.4	21.7	34.9
	MEAS	19.7	40.9	40.1	58.8	44.7	15.8	7.6	31.9	61.8	37.5	43.1	21.8	35.3
MEAN	CALC	23.1	27.1	39.5	47.3	37.6	14.6	13.6	11.6	19.2	24.7	20.5	23.4	
	MEAS	23.1	27.1	39.5	47.3	37.6	14.6	13.6	11.6	19.2	24.7	20.5	23.4	
STANDARD DEVIATION	CALC	4.7	6.4	10.3	16.0	15.9	7.5	12.6	8.0	13.3	9.0	10.9	7.9	
	MEAS	4.8	7.6	11.7	16.9	16.8	7.8	13.8	9.2	14.3	9.2	11.2	8.0	
COEFFICIENT OF SKEW	CALC	0.5	1.2	1.5	0.0	-0.1	2.3	1.0	0.1	0.9	-0.5	3.2	0.5	
	MEAS	0.3	0.3	-0.1	0.4	0.4	0.8	1.9	1.2	2.8	-0.6	0.7	0.4	
STANDARD ERROR		1.2	3.6	6.3	5.7	5.9	2.8	5.6	4.4	6.0	1.3	7.9	1.6	

NOTE: All values are in units of cubic meters per second with the exception of the coefficient of skew which is dimensionless.

TABLE 7 COMPARISON OF MEASURED AND CALCULATED STANDARD DEVIATIONS

MONTH	MONTHLY STANDARD DEVIATION (Cubic Meters/Second)			MONTH	MONTHLY STANDARD DEVIATION (Cubic Meters/Second)		
	Meas	Calc-1	Calc-2		Meas	Calc-1	Calc-2
JAN	4.83	4.65	2.28	JUL	13.76	12.61	10.20
FEB	7.57	6.43	4.83	AUG	9.17	8.02	5.72
MAR	11.71	10.25	5.15	SEP	14.27	13.29	8.34
APR	16.89	16.05	9.27	OCT	9.18	9.03	7.32
MAY	16.83	15.90	4.16	NOV	11.20	10.92	5.89
JUN	7.85	7.55	7.04	DEC	8.04	7.87	2.65

Calc-1 Standard Deviations using ranked regression equations

Calc-2 Standard Deviations using sequential regression equations

Meas Standard Deviations using measured discharge data at Baysville

LIST OF REFERENCES

LIST OF REFERENCES

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[3]Water Survey of Canada, Surface Water Data, Ontario 1981, Environment Canada.

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APPENDIX A
SUMMARY OF HYDROMETRIC DISCHARGE DATA

TABLE A-1 WHITSON RIVER AT CHELMSFORD
Station 2CF007

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1974	--	--	--	--	--	--	--	--	--	--	0.64	0.53
1975	0.36	0.35	0.46	6.89	1.59	0.98	0.51	0.42	0.48	0.65	0.86	0.72
1976	0.39	0.28	1.49	8.07	2.30	0.99	1.02	0.61	0.48	0.36	0.34	0.25
1977	0.17	0.18	1.25	5.57	0.76	0.41	0.40	0.36	0.53	1.02	1.08	0.32
1978	0.26	0.29	0.43	5.83	2.54	0.51	0.50	0.44	0.45	1.86	0.81	0.70
1979	0.39	0.31	2.00	10.20	3.27	0.75	0.81	0.48	0.11	0.39	2.04	0.99
1980	1.00	0.43	0.90	8.08	3.20	0.61	0.40	0.36	0.94	1.73	0.79	0.38
1981	0.33	1.26	2.54	5.67	1.41	0.75	0.80	0.37	0.92	1.65	1.05	0.42

TABLE A-2 WHITSON RIVER AT VAL CARON
Station 2CF008

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	--	--	--	7.82	--	--	--	--	--	--	--	--
1971	--	--	--	11.30	--	--	--	--	--	--	--	--
1972	--	--	--	--	--	--	--	--	--	--	--	--
1973	--	--	--	3.47	--	--	--	--	--	--	--	--
1974	--	--	--	7.27	--	--	--	--	--	--	3.34	0.83
1975	0.81	0.56	0.73	8.01	2.94	0.73	0.10	0.10	0.20	0.75	1.09	1.78
1976	0.26	0.25	1.62	8.23	2.23	0.69	0.21	0.18	0.90	1.04	0.70	0.34
1977	0.29	0.27	3.83	6.63	0.84	0.35	0.60	0.67	1.73	3.10	2.74	1.65
1978	0.91	0.62	0.62	6.67	2.99	0.63	0.70	0.98	1.81	4.20	1.57	1.15
1979	0.86	0.62	2.62	15.10	3.62	0.89	0.59	0.35	0.93	1.31	2.12	1.85
1980	1.31	0.54	0.72	9.32	3.03	0.86	0.52	0.56	1.32	2.51	1.53	0.75
1981	0.36	1.68	2.89	7.13	1.32	0.79	0.56	0.23	1.87	2.63	1.30	0.80

TABLE A3 VERMILLION RIVER NEAR CAPREOL
Station 2CF100

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	--	--	--	--	29.10	38.90	11.50	6.12	4.96	10.20	8.29	7.90
1971	--	--	--	--	28.70	10.00	3.56	1.89	1.15	2.05	4.02	6.44
1972	4.78	3.52	3.61	15.90	35.90	7.33	4.69	7.08	7.20	6.83	8.25	5.38
1973	4.54	4.38	13.60	21.50	20.90	12.60	7.25	6.14	3.87	4.92	7.16	6.05
1974	4.60	3.92	3.66	21.30	21.00	11.30	5.59	3.33	2.17	3.82	10.80	6.05
1975	--	--	--	--	24.90	11.90	5.35	2.25	1.67	2.32	4.58	8.84
1976	--	--	--	48.20	26.80	9.05	3.14	1.49	1.86	2.44	--	--
1977	--	--	--	--	11.20	3.75	3.07	2.06	3.86	8.21	8.92	7.27

TABLE A-4 DUCHESNAY RIVER NEAR NORTH BAY
Station 2DD008

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.20	0.18	0.25	6.22	4.25	3.26	5.86	1.19	1.98	1.98	1.61	0.74
1971	0.32	0.33	0.47	6.58	3.01	0.30	0.11	0.16	0.43	0.66	0.88	1.84
1972	0.69	0.37	0.32	5.31	5.95	1.14	0.63	3.71	0.66	1.47	1.49	0.68
1973	0.52	0.52	3.78	6.27	2.96	1.52	0.41	0.80	0.46	1.39	1.72	1.11
1974	0.52	1.06	0.54	7.33	3.09	2.70	0.52	0.47	0.45	1.49	4.21	1.00
1975	0.50	0.29	0.55	4.47	4.11	1.74	0.41	0.11	0.31	1.25	2.02	2.84
1976	0.40	0.19	1.84	6.79	2.95	0.64	1.44	0.39	0.91	0.89	0.51	0.37
1977	0.25	0.23	2.10	7.17	0.69	0.38	1.63	1.55	1.77	1.50	2.03	0.72
1978	0.40	0.43	0.27	4.21	4.13	0.57	0.54	1.31	2.38	2.49	1.19	0.60
1979	0.44	0.43	3.27	8.91	2.90	0.74	0.58	0.58	0.96	1.71	1.90	1.53
1980	0.69	0.29	1.76	8.50	1.80	1.08	1.18	0.63	2.79	2.46	1.60	0.65
1981	0.32	1.50	1.56	7.32	2.15	1.34	0.31	0.30	1.93	3.55	1.16	0.67

TABLE A-5 VEUVE RIVER NEAR VERNER
Station 2DD012

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973	--	--	--	--	21.60	5.75	1.79	5.92	0.69	2.28	8.83	10.30
1974	2.81	0.88	1.33	36.10	13.80	11.20	1.43	0.74	2.81	12.90	30.80	5.70
1975	3.49	1.64	1.70	49.10	20.30	5.55	0.75	0.41	0.30	0.91	4.04	13.60
1976	1.87	1.25	20.20	68.30	23.20	3.26	0.84	0.92	1.41	2.39	4.77	2.42
1977	1.35	1.18	34.10	40.40	3.57	0.52	1.59	5.70	17.60	19.00	23.60	13.20
1978	4.15	2.31	1.93	50.60	25.00	1.98	0.97	1.84	14.90	25.50	9.65	6.10
1979	3.55	2.78	29.40	89.10	18.90	5.73	2.79	2.08	2.73	5.15	21.80	11.00
1980	9.02	1.97	10.00	68.90	18.40	3.22	2.26	1.82	10.80	18.40	11.80	4.74
1981	2.65	16.10	17.20	61.00	12.20	8.73	4.21	1.11	8.99	17.60	8.86	5.71

TABLE A-6 LA VASE RIVER AT NORTH BAY
Station 2DD013

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1974	--	--	1.23	3.83	1.54	0.59	0.13	0.22	0.54	0.68	2.03	0.38
1975	0.28	0.21	0.56	4.03	1.11	0.43	0.08	0.06	0.07	0.33	0.62	1.13
1976	0.13	0.13	3.32	2.68	2.10	0.18	0.25	0.09	0.11	0.19	0.36	0.22
1977	0.13	0.11	2.51	3.27	0.28	0.13	0.17	0.38	1.12	0.81	1.06	0.69
1978	0.26	0.17	0.14	4.19	0.80	0.14	0.16	0.55	1.05	1.20	0.73	0.42
1979	0.31	0.30	2.61	4.98	1.39	0.39	0.11	0.29	0.73	0.99	1.80	0.97
1980	0.38	0.11	1.23	4.65	0.82	0.59	0.87	0.58	2.39	2.49	1.28	0.57
1981	0.20	2.05	1.54	2.86	1.33	0.94	0.25	0.16	1.45	1.63	0.81	0.47

TABLE A-7 COMMANDA CREEK NEAR COMMANDA
Station 2DD015

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1974	--	--	--	--	--	--	--	--	--	--	2.90	1.35
1975	1.80	1.32	1.17	5.26	3.76	1.06	0.32	0.11	0.51	0.76	1.67	4.74
1976	0.92	0.82	4.99	6.44	2.21	0.83	1.02	0.30	0.47	0.52	0.81	0.94
1977	0.44	0.45	4.58	5.86	0.84	0.35	0.15	0.32	0.91	1.96	2.46	1.50
1978	0.86	0.54	0.47	4.74	3.34	0.83	0.20	0.42	0.83	1.79	1.43	1.37
1979	0.78	0.56	3.82	7.34	2.71	1.12	0.44	0.65	0.32	1.78	2.37	1.19
1980	1.02	0.43	1.83	7.72	1.63	2.19	1.24	0.99	1.43	2.92	2.17	1.08
1981	0.64	2.63	2.54	6.31	2.56	2.00	0.67	0.44	1.78	2.59	1.26	1.27

TABLE A-8 NORTH MAGNETAWAN NEAR BURK'S FALLS
Station 2EA005 (NET)

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	1.80	1.52	1.17	8.49	7.42	2.93	4.84	2.07	1.21	3.19	2.89	3.44
1971	1.38	0.95	1.67	11.40	6.87	2.42	1.03	0.98	0.94	1.19	1.81	3.35
1972	1.60	0.63	0.17	5.74	8.89	2.02	2.63	2.23	1.49	1.56	3.25	2.02
1973	2.10	1.80	8.69	7.99	4.29	2.12	2.25	2.11	0.60	1.47	1.74	2.87
1974	1.27	1.53	1.42	8.80	6.36	2.78	1.07	0.70	0.58	2.67	4.24	2.74
1975	1.82	1.33	1.82	6.35	7.95	1.53	0.36	0.55	1.30	2.70	2.67	4.08
1976	1.53	1.36	3.43	11.89	4.21	1.49	1.25	0.25	0.00	0.37	0.70	1.85
1977	0.80	0.48	2.28	10.76	2.69	0.41	0.80	0.14	0.78	5.05	5.49	4.05
1978	1.91	1.09	0.61	4.64	8.53	1.94	0.55	0.46	1.10	2.69	2.19	2.10
1979	1.71	1.22	4.39	10.00	5.97	2.19	0.48	1.14	0.90	2.23	4.43	4.29
1980	2.68	1.32	1.64	13.20	3.98	3.20	3.37	3.03	3.56	3.87	5.12	3.49
1981	1.32	2.52	5.01	11.10	4.57	2.70	1.98	1.76	6.70	6.05	2.34	2.23

TABLE A-9 NORTH MAGNETAWAN RIVER ABOVE PICKEREL LAKES
Station 2EA010

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.72	0.61	0.82	9.41	3.98	2.07	3.98	0.69	1.68	2.78	2.39	1.80
1971	1.14	0.69	1.00	10.40	4.13	1.21	0.57	0.71	0.67	0.76	1.60	2.84
1972	1.07	1.02	1.26	9.96	9.31	3.84	1.90	2.32	1.25	2.84	2.83	1.13
1973	1.19	0.99	5.51	8.01	3.82	2.82	1.41	1.18	1.03	1.71	2.76	3.01
1974	2.32	2.40	2.79	12.90	5.94	2.02	1.27	0.66	0.90	2.38	4.82	1.66
1975	1.76	1.38	1.88	8.85	5.55	0.98	0.94	0.53	2.52	2.68	2.79	5.51
1976	1.11	0.98	9.37	9.01	4.63	1.56	1.43	0.55	0.99	1.16	1.63	1.43
1977	0.74	0.52	6.11	9.04	1.56	0.70	0.61	0.72	2.34	3.78	4.19	2.55
1978	1.03	0.65	0.62	6.96	5.87	1.26	0.51	0.98	1.43	3.12	2.05	1.66
1979	1.04	0.87	6.81	10.70	3.83	1.30	0.88	0.71	0.92	2.92	4.63	2.71
1980	2.79	0.96	2.12	11.90	2.63	3.87	3.08	1.82	3.14	4.09	3.70	1.54
1981	1.02	5.57	3.14	9.70	3.96	2.71	2.67	1.66	5.70	5.55	2.26	1.94

TABLE A-10 SHAWANAGA RIVER AT NO. 69
Station 2EA012

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1974	--	--	--	20.40	7.77	3.10	0.85	0.09	0.09	2.07	9.03	3.53
1975	4.54	2.98	4.37	14.80	6.47	1.00	0.16	0.05	2.79	2.20	4.81	9.61
1976	2.75	3.02	12.30	13.90	3.91	1.26	0.46	0.08	0.04	0.05	0.67	1.94
1977	1.44	1.23	4.07	11.60	1.58	0.30	0.04	0.02	0.61	4.06	8.42	6.70
1978	2.56	1.55	1.29	16.40	5.07	1.38	--	--	--	--	--	--

TABLE A-11 ROSSEAU RIVER AT NO. 11
Station 2EB103

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	--	--	--	11.70	2.32	0.53	4.30	1.55	0.74	3.17	3.33	3.11
1971	--	--	--	19.10	3.83	0.44	0.12	0.11	0.13	0.16	0.87	4.18
1972	--	--	--	15.60	4.30	1.32	0.41	0.98	0.40	2.98	2.56	1.56
1973	--	--	--	9.51	3.29	1.90	0.48	2.21	0.33	2.04	4.43	2.47
1974	--	--	--	16.30	3.91	0.72	0.22	0.42	0.87	3.99	5.31	1.18
1975	--	--	--	15.20	4.27	0.44	0.15	0.11	0.46	0.86	1.52	5.09
1976	--	--	--	--	--	--	0.44	0.11	0.06	0.22	1.54	--
1977	--	--	--	6.96	0.75	0.25	0.62	--	2.95	4.74	6.43	--

TABLE A-12 BOB CREEK NEAR MINDEN
Station 2HF004

Discharge in Cubi Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	--	--	--	--	--	--	--	--	0.02	0.02	0.08	0.37
1976	0.14	0.15	1.32	0.88	0.12	0.02	0.02	0.01	0.04	0.04	0.09	0.07
1977	0.03	0.04	0.86	0.38	0.02	0.00	0.00	0.00	0.01	0.14	0.38	0.24
1978	0.13	0.05	0.08	0.96	0.24	0.01	0.00	0.01	0.00	0.09	0.22	0.15
1979	0.12	0.10	0.95	0.73	0.19	0.03	0.01	0.01	0.00	0.22	0.45	0.40
1980	0.13	0.01	0.46	0.99	0.07	0.20	0.32	0.04	0.05	0.36	0.28	0.20
1981	0.05	1.15	0.39	0.39	0.20	0.05	0.01	0.02	0.18	0.16	0.17	0.11

TABLE A-13 INDIAN RIVER NEAR PEMBROKE
Station 2KC014

Discharge in Cubic Metres per Second

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.81	1.11	1.36	17.10	10.70	3.32	2.82	0.69	0.70	1.44	2.36	2.45
1971	1.36	1.38	2.15	22.50	10.40	3.33	1.24	0.65	0.46	0.39	0.85	2.20
1972	1.00	0.79	0.87	15.00	17.50	9.48	4.66	4.41	2.63	5.98	11.90	5.41
1973	4.06	3.02	10.90	29.70	10.40	9.32	3.60	1.74	1.31	1.64	2.76	3.35
1974	2.08	2.22	4.02	25.80	19.80	5.43	2.07	1.39	0.88	1.16	4.19	3.23
1975	2.64	1.78	3.36	17.90	8.77	2.45	0.85	0.47	0.51	0.74	0.93	1.81
1976	1.28	1.52	11.20	22.40	9.04	3.88	5.42	1.70	1.79	1.95	2.96	1.87
1977	1.43	1.20	8.65	13.90	4.02	1.24	0.56	0.45	0.67	2.00	4.24	5.47
1978	3.46	2.34	1.82	23.00	12.50	3.11	0.85	0.85	0.64	0.90	1.14	1.14
1979	1.27	1.20	5.54	20.70	11.60	3.92	1.39	0.80	1.17	2.28	3.35	3.50
1980	1.74	0.85	4.86	16.00	7.45	4.02	5.72	3.24	1.81	5.04	5.25	4.02
1981	2.01	10.70	11.20	11.10	7.29	3.20	1.47	1.02	4.24	4.30	3.52	3.27

APPENDIX B
SUMMARY OF CLIMATOLOGICAL DATA

TABLE B-1 SUMMARY OF METEOROLOGICAL DATA FOR BURK'S FALLS

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	Precipitation	63.5	--	70.9	64.8	67.8	85.1	181.4	59.9	108.2	108.5	69.9	96.8
	Mean Max Daily Temp	-8.3	--	--	10.3	16.1	22.2	24.3	23.9	17.9	13.5	4.2	-5.9
	Mean Min Daily Temp	-22.1	--	--	-3.1	4.1	7.1	12.2	9.4	7.1	2.3	-3.4	-17.7
	Dmax	0.0	--	--									15.6
	Dmin	0.0	--	--									2.8
1971	Precipitation	133.1	146.8	92.7	40.9	57.9	75.2	72.6	100.8	57.9	49.8	100.3	108.0
	Mean Max Daily Temp	-8.9	-3.9	-0.6	7.3	18.0	23.3	22.6	21.9	20.7	16.6	2.5	-1.2
	Mean Min Daily Temp	-21.8	-15.6	-14.9	-4.6	0.9	8.4	9.2	8.7	7.2	5.2	-4.8	-12.1
	Dmax	2.8	13.9	42.0									41.7
	Dmin	0.0	0.0	0.0									1.7
1972	Precipitation	143.8	112.8	78.5	63.2	68.1	112.8	184.2	163.1	66.3	90.9	65.3	190.8
	Mean Max Daily Temp	-3.9	-6.6	-2.1	6.5	19.0	20.4	23.9	21.4	18.3	8.7	1.6	-3.2
	Mean Min Daily Temp	-12.7	-21.1	-15.2	-6.1	2.4	6.4	10.1	9.8	6.2	-1.3	-4.9	-14.9
	Dmax	17.8	2.8	41.1									20.6
	Dmin	0.0	0.0	0.0									0.0
1973	Precipitation	108.0	53.8	101.3	76.5	120.9	148.6	133.9	118.6	77.5	100.1	85.3	96.0
	Mean Max Daily Temp	-3.9	-5.1	5.6	10.2	15.4	22.8	24.8	24.3	18.2	14.6	3.0	-3.8
	Mean Min Daily Temp	-15.4	-20.9	-1.3	-2.2	1.7	9.2	10.9	11.9	4.9	2.4	-4.2	-12.8
	Dmax	45.0	8.3	174.5									37.8
	Dmin	4.4	0.0	17.8									0.6
1974	Precipitation	137.9	98.8	60.7	94.5	107.2	102.6	101.9	127.8	136.9	126.2	112.8	51.0
	Mean Max Daily Temp	-4.8	-6.7	-0.2	10.2	14.1	21.9	23.6	23.8	16.4	9.7	3.9	-0.5
	Mean Min Daily Temp	-16.4	-21.4	-11.5	-3.0	1.2	7.3	9.4	9.0	3.1	-2.3	-5.2	-9.6
	Dmax	32.2	0.0	51.7									27.2
	Dmin	0.0	0.0	2.8									0.0
1975	Precipitation	174.5	123.7	63.0	85.9	26.4	69.6	103.4	119.6	142.5	62.5	109.2	73.4
	Mean Max Daily Temp	-3.6	-3.4	-0.3	5.8	21.5	23.7	25.9	24.2	16.2	12.9	7.6	-4.3
	Mean Min Daily Temp	-15.7	-15.7	-14.3	-8.3	4.4	7.8	9.9	8.4	3.6	1.2	-1.6	-15.8
	Dmax	25.0	23.9	52.8									35.0
	Dmin	0.0	0.0	0.0									0.0
1976	Precipitation	78.7	114.8	152.9	--	121.2	90.4	74.2	62.0	84.3	71.9	113.5	109.0
	Mean Max Daily Temp	-8.4	-1.2	2.6	--	15.6	24.8	23.4	23.8	17.8	8.9	0.6	-7.3
	Mean Min Daily Temp	-22.4	-14.8	-10.0	--	3.2	9.6	10.7	7.9	5.3	-1.7	-7.3	-21.1
	Dmax	10.0	38.3	134.5									1.7
	Dmin	0.0	0.0	22.2									0.0
1977	Precipitation	80.0	99.3	92.7	89.5	33.0	97.1	86.2	119.8	163.6	84.5	168.4	80.0
	Mean Max Daily Temp	-10.8	-3.4	5.5	12.3	21.3	21.1	24.9	21.2	16.5	11.3	4.7	-3.6
	Mean Min Daily Temp	-23.2	-13.5	-6.9	-3.3	3.6	6.9	11.3	9.7	7.5	-0.2	-3.9	-12.4
	Dmax	0.0	11.2	188.3									16.5
	Dmin	0.0	0.0	13.3									0.0
1978	Precipitation	91.4	30.2	66.8	74.4	55.8	105.0	85.0	161.4	138.0	87.4	77.0	110.4
	Mean Max Daily Temp	-8.2	-7.0	-0.4	6.1	20.0	21.6	23.9	23.5	16.8	10.2	3.7	-3.1
	Mean Min Daily Temp	-19.8	-20.8	-14.7	-4.2	5.2	7.3	9.8	10.0	4.7	-0.1	-5.8	-14.4
	Dmax	4.0	0.0	44.5									8.5
	Dmin	0.0	0.0	0.0									0.0
1979	Precipitation	188.0	74.0	13.2	--	--	71.8	96.0	88.2	100.6	141.4	118.2	108.3
	Mean Max Daily Temp	-8.8	-5.5	--	--	17.8	23.0	26.0	21.6	18.6	11.5	5.0	-1.5
	Mean Min Daily Temp	-17.5	-18.2	--	--	4.6	8.2	10.5	9.8	6.5	3.3	-2.0	-12.7
	Dmax	3.0	15.5	--									27.5
	Dmin	0.0	0.0	--									0.0
1980	Precipitation	133.7	60.4	113.3	101.8	60.0	157.2	92.4	124.2	96.8	123.0	92.6	116.8
	Mean Max Daily Temp	-5.1	-6.7	0.8	10.1	18.8	19.0	23.8	24.2	16.8	8.5	2.3	-6.6
	Mean Min Daily Temp	-16.4	-18.5	-8.6	-0.9	3.7	5.7	11.6	13.0	6.1	-0.4	-5.9	-20.7
	Dmax	22.5	1.0	98.5									9.5
	Dmin	0.5	0.0	2.0									0.0
1981	Precipitation	80.4	107.4	67.2	96.2	81.4	109.8	94.0	137.2	165.2	109.2	49.6	118.1
	Mean Max Daily Temp	-8.4	0.4	2.2	10.9	16.3	21.5	25.4	23.5	16.4	9.3	4.7	-2.7
	Mean Min Daily Temp	-23.2	-9.7	-8.6	-1.5	2.4	8.7	10.7	10.0	6.5	-1.1	-6.0	-11.3
	Dmax	8.5	94.7	114.2									9.5
	Dmin	0.0	17.5	14.0									0.0

TABLE B-2 SUMMARY OF METEOROLOGICAL DATA FOR CHALK RIVER

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	Precipitation	22.1	42.4	57.7	46.7	88.4	62.0	112.3	24.4	79.8	75.2	50.5	65.0
	Mean Max Daily Temp	-10.0	-6.3	1.0	11.2	17.2	23.2	25.2	24.8	18.3	13.4	4.4	-7.1
	Mean Min Daily Temp	-21.2	-18.6	-10.8	-1.1	4.9	9.6	13.9	11.9	8.9	3.7	-2.1	-15.4
	Dmax	1.7	20.6	62.2									15.0
	Dmin	0.0	0.0	0.0									0.0
1971	Precipitation	54.6	121.2	46.7	22.4	43.7	89.4	43.4	61.5	34.5	29.5	66.3	94.5
	Mean Max Daily Temp	-9.8	-4.4	0.7	8.3	19.6	24.4	23.9	23.8	21.7	16.2	2.4	-3.6
	Mean Min Daily Temp	-20.6	-15.2	-11.2	-2.6	4.9	10.2	11.6	11.0	9.6	5.7	-3.6	-13.7
	Dmax	1.1	18.9	54.5									37.8
	Dmin	0.0	0.0	0.0									0.0
1972	Precipitation	35.6	82.3	81.8	54.6	36.1	142.5	138.4	123.2	89.2	81.8	72.9	126.2
	Mean Max Daily Temp	-4.0	-6.7	-1.6	7.7	20.2	22.1	25.2	22.5	18.6	8.9	2.0	-5.3
	Mean Min Daily Temp	-16.9	-19.4	-12.6	-3.2	6.1	10.2	13.8	12.6	8.4	1.2	-0.4	-14.8
	Dmax	33.9	5.0	41.7									3.3
	Dmin	0.0	0.0	0.6									0.0
1973	Precipitation	30.7	43.9	91.4	64.8	74.7	239.0	73.9	63.8	41.9	74.9	64.5	107.2
	Mean Max Daily Temp	-4.6	-5.5	5.4	10.7	16.8	23.6	27.0	25.9	18.8	14.6	2.6	-3.8
	Mean Min Daily Temp	-14.2	-18.9	-2.3	-0.8	5.0	12.2	13.8	15.4	8.7	5.3	-1.6	-11.2
	Dmax	21.1	6.1	168.5									33.9
	Dmin	8.9	0.0	12.8									3.9
1974	Precipitation	62.7	59.4	50.3	92.5	125.0	62.2	85.6	79.5	53.8	51.8	108.5	51.1
	Mean Max Daily Temp	-5.7	-5.8	0.3	11.1	14.9	22.8	25.3	24.7	17.3	10.1	3.5	-0.7
	Mean Min Daily Temp	-15.6	-18.1	-10.5	-1.2	3.6	11.2	13.6	12.9	6.4	0.6	-2.4	-7.2
	Dmax	27.8	9.4	62.2									26.1
	Dmin	0.6	0.0	3.3									0.6
1975	Precipitation	63.2	42.9	60.5	44.2	37.8	77.7	62.7	28.4	77.2	93.7	55.9	49.3
	Mean Max Daily Temp	-5.1	-3.6	0.7	7.9	23.8	24.9	27.8	26.3	17.7	13.1	7.1	-5.6
	Mean Min Daily Temp	-14.4	-13.8	-10.4	-4.1	8.1	12.4	14.5	13.3	7.9	3.3	-1.3	-15.8
	Dmax	19.4	18.4	63.3									26.7
	Dmin	1.6	0.0	0.6									0.0
1976	Precipitation	55.6	67.8	116.1	9.9	111.3	76.2	51.6	84.8	64.0	47.8	47.0	39.4
	Mean Max Daily Temp	-8.9	-1.2	1.9	13.7	16.4	26.2	24.7	24.1	18.2	9.7	0.8	-7.5
	Mean Min Daily Temp	-14.3	-13.7	-9.9	0.1	4.8	13.0	12.9	11.9	7.6	0.1	-5.6	-19.1
	Dmax	4.4	32.2	127.2									0.6
	Dmin	0.0	0.0	7.8									0.0
1977	Precipitation	45.0	45.5	61.3	83.0	25.6	63.4	58.5	107.9	91.3	50.6	103.6	69.0
	Mean Max Daily Temp	-9.1	-3.8	6.7	12.9	22.7	21.9	26.8	23.2	17.5	11.5	5.1	-5.0
	Mean Min Daily Temp	-19.0	-12.6	-4.4	-1.0	7.0	10.3	13.7	12.8	9.5	1.7	-1.6	-12.4
	Dmax	0.0	13.4	216.1									16.2
	Dmin	0.0	0.0	20.5									1.1
1978	Precipitation	80.0	3.9	50.9	80.2	46.5	81.8	43.4	135.8	72.9	47.7	70.8	110.8
	Mean Max Daily Temp	-8.1	-6.1	0.7	7.5	21.4	22.9	25.6	24.4	17.1	10.8	5.1	-3.2
	Mean Min Daily Temp	17.7	-18.6	-11.4	-2.6	8.2	10.1	13.5	12.4	6.5	2.0	-4.9	-12.0
	Dmax	7.2	0.0	65.7									21.0
	Dmin	1.1	0.0	0.0									0.0
1979	Precipitation	75.3	22.3	33.6	86.9	94.4	54.2	93.3	55.9	86.0	158.0	74.3	42.8
	Mean Max Daily Temp	-8.3	-8.7	4.9	10.0	18.3	23.8	26.5	22.5	19.4	10.4	5.3	-2.4
	Mean Min Daily Temp	-17.2	-20.9	-5.7	-0.5	6.0	10.3	14.1	11.6	7.2	2.9	-1.8	-10.6
	Dmax	9.5	23.5	166.9									33.0
	Dmin	0.0	0.0	15.0									0.0
1980	Precipitation	33.4	22.0	70.7	86.4	71.3	131.2	158.3	72.6	110.7	116.4	57.5	53.2
	Mean Max Daily Temp	-5.7	-5.7	1.8	11.1	19.5	20.6	25.5	24.7	17.3	9.0	1.6	-8.9
	Mean Min Daily Temp	-15.7	-17.1	-9.6	0.6	5.2	8.1	13.7	14.7	6.9	1.2	-5.0	-20.8
	Dmax	13.0	4.0	107.8									3.5
	Dmin	0.0	0.0	2.5									0.0
1981	Precipitation	18.7	74.7	66.6	76.3	79.5	80.8	43.1	129.1	146.0	84.3	43.3	42.0
	Mean Max Daily Temp	-10.2	1.1	3.3	11.7	17.7	23.2	26.5	24.4	16.8	9.5	4.9	-2.2
	Mean Min Daily Temp	-21.8	-10.4	-6.2	0.5	5.3	11.4	13.5	12.5	9.1	-1.5	-3.2	-8.6
	Dmax	7.5	105.5	131.8									19.5
	Dmin	0.0	16.5	13.0									0.5

TABLE B-3 SUMMARY OF METEOROLOGICAL DATA FOR HUNTSVILLE

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	Precipitation	60.7	41.9	60.2	68.3	106.4	91.2	202.7	65.3	97.5	101.1	71.1	111.8
	Mean Max Daily Temp	-7.8	-4.1	1.0	10.7	16.4	22.9	24.9	23.9	18.0	13.8	5.2	-4.6
	Mean Min Daily Temp	-19.0	-16.1	-11.7	-1.9	6.0	10.7	14.6	13.5	9.9	5.0	-0.6	-14.1
	Dmax	0.0	25.0	61.0									22.8
	Dmin	0.0	0.0	0.6									2.8
1971	Precipitation	99.8	133.7	63.8	35.6	45.0	75.2	67.1	93.5	31.2	55.1	85.9	114.3
	Mean Max Daily Temp	-7.6	-2.7	0.9	0.3	18.2	23.6	23.1	22.7	20.9	16.9	3.7	-0.1
	Mean Min Daily Temp	-18.8	-14.6	-12.4	-2.2	3.8	11.6	12.8	12.0	11.4	7.5	-1.8	9.4
	Dmax	5.6	21.1	27.2									53.3
	Dmin	0.0	0.0	0.0									7.2
1972	Precipitation	135.4	89.4	64.3	64.0	83.3	80.0	125.7	118.9	79.5	109.5	64.3	128.3
	Mean Max Daily Temp	-2.9	-5.2	-1.1	7.2	19.3	20.4	23.9	22.2	18.9	9.4	2.3	-2.1
	Mean Min Daily Temp	-14.8	-17.9	-12.1	-3.4	5.9	9.8	13.8	13.0	9.2	1.1	-2.4	-10.9
	Dmax	35.0	6.1	52.8									33.9
	Dmin	0.0	0.0	1.1									0.6
1973	Precipitation	119.4	53.3	76.7	58.9	102.6	235.5	71.6	46.2	54.6	83.1	93.0	90.7
	Mean Max Daily Temp	-3.3	-3.7	5.9	10.6	15.5	22.9	25.2	24.9	18.9	14.7	3.9	-2.7
	Mean Min Daily Temp	-12.7	-17.1	-1.2	-0.1	4.9	12.4	14.6	15.7	9.0	5.3	-1.5	-10.3
	Dmax	36.1	117.0	173.5									41.1
	Dmin	5.0	0.0	32.8									6.7
1974	Precipitation	148.8	52.6	55.1	100.1	95.8	50.0	48.8	117.6	129.5	104.1	104.4	43.9
	Mean Max Daily Temp	-3.9	-5.1	0.3	11.0	13.9	21.9	23.9	23.9	16.9	10.4	4.4	0.0
	Mean Min Daily Temp	-14.1	-18.1	-8.8	-0.7	4.0	11.6	13.2	13.3	7.4	0.6	-1.5	-6.6
	Dmax	33.3	10.6	50.6									31.1
	Dmin	0.0	0.0	2.2									0.0
1975	Precipitation	114.0	91.7	65.8	56.1	57.2	52.8	87.1	93.2	105.4	54.6	100.8	105.7
	Mean Max Daily Temp	-2.7	-2.5	0.3	6.4	21.4	23.6	25.6	24.3	16.8	13.6	8.6	-3.4
	Mean Min Daily Temp	-11.9	-12.6	-11.3	-4.8	8.2	13.6	14.2	13.1	7.7	4.7	-0.1	-12.9
	Dmax	26.1	25.0	60.6									37.2
	Dmin	2.8	1.7	2.2									0.0
1976	Precipitation	92.2	102.6	114.0	23.1	58.4	83.3	42.2	66.6	152.4	53.3	120.7	82.8
	Mean Max Daily Temp	-6.9	-0.4	3.2	11.7	15.5	25.0	23.9	23.7	18.0	10.1	1.8	-6.3
	Mean Min Daily Temp	-20.1	-13.3	-7.8	0.2	5.0	12.9	13.7	12.2	7.7	2.3	-4.8	-18.6
	Dmax	10.6	54.4	166.7									6.1
	Dmin	0.0	0.0	22.2									0.0
1977	Precipitation	115.0	48.9	59.4	55.6	23.6	61.8	70.9	115.8	118.0	83.6	147.0	110.2
	Mean Max Daily Temp	-9.5	-3.2	5.8	12.8	21.3	21.7	25.2	22.6	17.7	11.8	5.5	-4.0
	Mean Min Daily Temp	-20.0	-12.6	-5.4	0.6	7.0	10.3	14.8	12.3	9.9	1.8	-1.4	-11.3
	Dmax	0.0	9.6	185.4									11.0
	Dmin	0.0	0.0	5.6									0.0
1978	Precipitation	56.9	13.6	34.7	51.8	41.6	88.4	87.0	145.2	110.8	61.6	82.1	83.0
	Mean Max Daily Temp	-7.6	-6.7	0.1	6.8	20.0	22.1	24.4	24.3	16.3*	9.5*	3.4*	-2.7*
	Mean Min Daily Temp	-18.2	-19.6	-13.6	-3.1	6.9	9.9	13.2	13.2	5.8*	0.3*	-5.2*	-8.7*
	Dmax	7.5	0.0	29.7									21.0*
	Dmin	0.0	0.0	0.0									0.0*
1979	Precipitation	161.0	44.4	91.2*	28.0	116.0	52.6	85.6	94.5	90.4	138.3	88.3	55.4
	Mean Max Daily Temp	-7.1	-7.6	4.8	9.4	17.4	22.9	25.9	22.1	19.3	10.6	6.1	-0.3
	Mean Min Daily Temp	-15.0	-19.6	-5.5	-0.8	6.3	9.4*	13.7	12.3	8.7	3.3	-0.5	-8.6
	Dmax	4.4	13.8	167.1									30.0
	Dmin	0.0	0.0	9.4									1.1
1980	Precipitation	64.9	48.7	74.1	86.7	60.7	137.1	116.6	127.7	95.8	119.8	40.6	143.0
	Mean Max Daily Temp	-3.6	-5.6	1.3	10.7	19.1	19.2	24.9	24.7	17.6	8.8	2.9	-6.0
	Mean Min Daily Temp	-13.6	-16.9	-5.0*	0.3	6.0	7.8	13.3	15.3	8.4	1.6	-4.0	-17.6
	Dmax	17.2	1.7	72.5									6.4
	Dmin	0.6	0.0	-15.0*									0.3
1981	Precipitation	63.2	64.3	67.8	89.0	64.4*	89.7	67.2	200.7	99.6*	48.6*	87.2*	43.0
	Mean Max Daily Temp	-8.4	0.7	2.6	11.1	15.6*	21.8	25.5	23.9	15.6*	8.4*	3.8*	-2.3
	Mean Min Daily Temp	-22.3	-9.1	-7.3	0.6	3.2*	11.0	14.0	13.2	7.6*	0.4*	-3.5*	-8.7
	Dmax	5.3	54.9	68.0									6.4
	Dmin	0.0	8.9	4.4									0.3

* Data from Dwight

TABLE B-4 SUMMARY OF METEOROLOGICAL DATA FOR MINDEN

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	Precipitation	97.8	120.9	67.1	74.9	74.2	91.9	76.7	88.4	106.4	50.0	91.4	96.0
	Mean Max Daily Temp	-2.5	-2.2	0.7	7.2	22.4	24.6	26.7	25.1	17.3	14.4	9.1	-3.1
	Mean Min Daily Temp	-12.2	-13.2	-12.1	-6.1	6.1	10.5	11.4	10.2	5.9	2.2	-1.4	-13.3
	Dmax	23.9	28.3	57.8									38.9
	Dmin	2.2	1.6	5.0									0.0
1976	Precipitation	98.0	134.1	140.7	22.6	80.3	64.5	83.8	110.7	105.7	59.9	63.0	73.7
	Mean Max Daily Temp	-6.7	0.2	3.1	13.6	16.5	25.4	24.4	24.2	19.2	9.9	2.1	-5.6
	Mean Min Daily Temp	-20.7	-12.4	-9.2	-1.2	2.5	10.2	11.1	9.7	5.7	-0.8	-6.3	-18.9
	Dmax	8.9	67.8	142.2									10.0
	Dmin	0.0	0.0	9.4									0.0
1977	Precipitation	81.1	73.4	86.8	33.4	16.0	86.3	60.1	132.7	89.2	95.0	138.5	116.3
	Mean Max Daily Temp	-8.9	-4.0	6.0	13.4	22.7	22.8	25.9	22.5	18.1	12.3	6.0	-3.2
	Mean Min Daily Temp	-20.3	-14.0	-6.0	-0.9	3.4	7.6	11.8	10.4	9.2	0.8	-2.2	-12.2
	Dmax	0.0	15.5	201.0									19.6
	Dmin	0.0	0.0	10.1									2.8
1978	Precipitation	103.4	10.1	72.2	58.7	81.3	89.5	98.2	126.5	78.3	23.8	77.0	102.3
	Mean Max Daily Temp	-6.9	-5.1	1.1	7.6	20.7	22.5	25.3	25.0	18.7	11.7	5.7	-1.6
	Mean Min Daily Temp	-18.0	-20.1	-13.2	-4.0	5.7	7.8	11.0	11.1	5.6	-0.5	-4.8	-11.1
	Dmax	7.7	0.0	70.2									26.5
	Dmin	0.0	0.0	0.0									0.0
1979	Precipitation	84.3	51.4	56.5	99.6	110.2	104.9	78.2	88.8	41.4	156.8	156.7	98.4
	Mean Max Daily Temp	-6.3	-6.9	5.5	10.2	17.9	23.3	26.4	22.8	20.3	11.5	6.4	-0.5
	Mean Min Daily Temp	-15.2	-21.7	-5.5	-1.3	5.2	8.8	11.3	10.7	6.3	2.5	-1.6	-9.3
	Dmax	7.0	26.5	198.0									48.5
	Dmin	0.0	0.0	16.0									2.0
1980	Precipitation	84.6	26.0	109.4	106.2	68.7	102.6	145.6	97.1	71.5	137.4	74.2	142.8
	Mean Max Daily Temp	-3.0	-4.9	2.0	11.4	20.2	19.7	25.1	25.2	18.7	9.9	3.2	-5.1
	Mean Min Daily Temp	-13.3	-17.7	-10.1	-0.5	4.1	5.6	11.6	12.9	6.2	0.1	-5.1	-19.0
	Dmax	37.0	4.5	109.0									13.0
	Dmin	0.0	0.0	3.0									0.0
1981	Precipitation	32.0	112.8	49.7	83.0	85.2	103.1	54.2	91.7	116.7	80.9	61.3	67.0
	Mean Max Daily Temp	-8.0	1.3	4.6	11.0	17.7	22.8	25.6	24.5	17.3	10.2	6.0	-1.8
	Mean Min Daily Temp	-22.8	-9.8	-6.9	-0.9	2.9	9.1	11.0	10.3	6.9	-0.9	-5.4	-10.2
	Dmax	10.0	91.9	163.6									18.0
	Dmin	0.0	15.5	28.0									0.0

TABLE B-5 SUMMARY OF METEOROLOGICAL DATA FOR NORTH BAY

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	Precipitation	39.1	--	36.8	61.0	167.4	125.7	227.8	135.9	156.7	69.9	39.1	82.3
	Mean Max Daily Temp	-9.7	--	0.4	10.6	15.8	22.9	25.1	24.7	18.2	13.8	3.1	-7.1
	Mean Min Daily Temp	-21.1	--	-11.1	-1.3	4.9	10.5	14.9	13.6	9.1	4.3	-3.8	--
	Dmax	1.7	0.0	58.0									13.9
	Dmin	0.0	0.0	0.0									1.7
1971	Precipitation	54.9	99.6	63.8	37.6	53.1	32.3	58.4	88.4	89.9	66.3	72.6	91.7
	Mean Max Daily Temp	-9.8	-4.1	0.3	8.5	18.2	24.1	24.1	22.7	21.1	15.7	2.7	-1.5
	Mean Min Daily Temp	-20.4	-15.2	-11.7	-2.0	4.2	11.7	12.2	11.7	10.8	7.1	-3.0	-11.1
	Dmax	1.7	19.4	56.1									35.6
	Dmin	0.0	0.0	1.7									3.9
1972	Precipitation	78.5	87.1	65.3	51.3	49.0	74.7	104.9	210.8	40.9	69.1	45.0	125.2
	Mean Max Daily Temp	-3.9	-7.1	-2.0	7.3	19.8	21.3	24.2	21.7	18.2	8.9	2.1	-5.6
	Mean Min Daily Temp	16.1	-19.6	-12.8	-4.1	6.3	9.7	13.2	12.0	8.4	0.6	-4.1	-14.8
	Dmax	28.9	11.7	42.8									6.1
	Dmin	0.0	0.0	0.0									0.0
1973	Precipitation	56.1	31.5	65.3	50.5	109.2	163.3	97.8	93.7	58.2	90.4	67.3	74.9
	Mean Max Daily Temp	-4.2	-6.1	5.8	10.6	16.3	23.1	25.8	24.3	16.9	14.8	2.3	-4.5
	Mean Min Daily Temp	-13.3	-19.1	-2.4	-0.5	4.3	12.7	14.4	15.2	6.8	5.3	-3.3	-12.1
	Dmax	30.0	5.0	185.9									27.8
	Dmin	5.0	0.0	16.7									1.7
1974	Precipitation	79.2	63.5	31.5	114.6	104.6	74.4	66.5	85.6	100.6	124.0	68.8	55.6
	Mean Max Daily Temp	-7.2	-7.1	0.0	9.4	14.1	22.5	24.1	24.1	16.3	9.3	3.3	-0.5
	Mean Min Daily Temp	-16.4	-19.6	-10.3	-1.7	4.3	11.9	13.9	12.7	6.4	0.2	-2.2	-7.6
	Dmax	22.2	7.2	50.6									29.4
	Dmin	0.0	0.0	1.7									0.6
1975	Precipitation	117.9	83.8	58.2	53.6	74.7	46.7	141.5	25.1	84.8	89.2	131.3	61.0
	Mean Max Daily Temp	-5.3	-3.9	-0.1	6.7	21.7	24.6	26.8	24.4	16.6	13.0	6.7	-5.2
	Mean Min Daily Temp	-16.1	-13.9	-11.6	-4.9	9.0	12.9	15.2	11.3	7.9	3.9	-1.2	-14.6
	Dmax	12.2	24.4	56.1									29.4
	Dmin	0.0	0.0	0.0									0.0
1976	Precipitation	68.6	111.3	95.8	12.4	116.6	76.2	80.8	48.5	99.6	50.3	88.9	58.4
	Mean Max Daily Temp	-8.8	-1.7	-0.1	11.2	16.1	25.1	23.8	23.6	17.7	9.2	0.8	-9.1
	Mean Min Daily Temp	-21.2	-15.1	-11.2	-0.1	5.2	13.5	13.7	11.9	7.2	0.8	-5.4	-21.3
	Dmax	3.3	52.8	103.9									0.6
	Dmin	0.0	0.0	8.9									0.0
1977	Precipitation	74.9	76.9	74.9	52.4	40.3	64.8	142.1	141.7	140.2	45.8	95.2	75.3
	Mean Max Daily Temp	-10.1	-5.0	5.9	12.4	20.1	20.0	24.8	21.4	15.6	11.2	5.0	-4.4
	Mean Min Daily Temp	-19.5	-13.8	-4.9	-0.8	6.6	9.2	14.0	12.3	8.1	1.8	-2.0	-10.9
	Dmax	0.0	14.0	192.3									12.9
	Dmin	0.0	0.0	18.5									0.0
1978	Precipitation	66.2	16.2	36.3	45.9	45.5	65.9	109.6	166.1	134.6	79.9	61.2	106.9
	Mean Max Daily Temp	-9.8	-6.9	-0.1	7.0	21.3	21.7	24.6	22.7	16.5	10.1	3.6	-4.3
	Mean Min Daily Temp	-18.6	-19.0	-13.2	-3.0	8.5	10.3	13.5	12.3	8.0	2.3	-4.4	-13.4
	Dmax	1.1	0.0	55.1									11.5
	Dmin	0.0	0.0	0.0									0.0
1979	Precipitation	87.2	37.5	89.6	100.7	80.9	78.4	43.4	118.6	71.6	117.2	96.1	67.4
	Mean Max Daily Temp	-9.2	-10.1	3.1	8.8	16.5	21.4	25.7	21.2	17.8	9.5	5.1	-1.9
	Mean Min Daily Temp	-17.5	-20.8	-7.6	-1.0	5.5	10.1	14.9	13.0	9.1	3.7	-1.1	-10.2
	Dmax	5.2	8.0	130.3									32.5
	Dmin	0.0	0.0	2.9									2.0
1980	Precipitation	69.0	47.0	121.4	92.0	39.6	138.6	134.8	85.8	173.8	105.5	80.2	58.6
	Mean Max Daily Temp	-5.7	-7.0	1.0	9.2	18.8	17.7	23.9	23.8	15.6	7.0	2.2	-9.2
	Mean Min Daily Temp	-14.6	-16.9	-9.3	-0.3	6.4	7.3	14.1	15.0	5.6	-0.7	-4.1	-20.7
	Dmax	20.5	2.0	86.0									3.8
	Dmin	0.0	0.0	3.0									0.0
1981	Precipitation	33.4	75.6	77.2	100.7	74.8	126.4	31.6	132.1	165.9	112.8	40.8	43.4
	Mean Max Daily Temp	-9.4	-1.2	0.6	9.5	16.7	22.0	25.2	24.1	16.5	9.4	5.0	-2.9
	Mean Min Daily Temp	-20.3	-10.4	-8.0	-1.4	5.0	12.2	13.7	13.5	9.1	0.9	-3.4	-9.3
	Dmax	8.5	59.1	77.6									19.0
	Dmin	0.0	10.7	8.7									1.0

TABLE B-6 SUMMARY OF METEOROLOGICAL DATA FOR SUDBURY

Precipitation in Millimetres and Temperature in Degrees Celcius

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	Precipitation	37.1	31.0	40.6	56.1	132.6	94.7	146.1	70.6	257.3	67.1	66.8	57.9
	Mean Max Daily Temp	-10.7	-7.6	-1.0	9.9	14.2	22.7	24.8	24.3	18.0	12.8	3.1	-6.6
	Mean Min Daily Temp	-21.0	-20.4	-12.2	-1.4	3.7	11.4	15.4	12.6	9.9	3.6	-4.2	-15.0
	Dmax	0.0	8.9	35.6									10.6
	Dmin	0.0	0.0	0.0									0.0
1971	Precipitation	67.1	90.2	50.3	32.0	62.5	50.5	95.0	55.4	69.1	61.5	71.6	93.2
	Mean Max Daily Temp	-10.8	-4.6	-0.1	6.2	17.7	24.2	23.7	22.3	21.2	14.2	1.7	-3.7
	Mean Min Daily Temp	-21.2	-15.4	-11.8	-3.6	4.7	11.4	13.1	10.9	11.4	6.4	-4.8	-13.1
	Dmax	0.0	18.9	42.2									26.7
	Dmin	0.0	0.0	1.1									1.1
1972	Precipitation	72.6	79.2	65.8	60.7	45.7	111.5	78.2	115.6	102.1	36.3	31.2	87.6
	Mean Max Daily Temp	-5.3	-7.3	-3.9	4.9	19.4	20.8	24.7	20.9	16.9	7.5	0.3	-6.9
	Mean Min Daily Temp	-18.4	-19.1	-14.7	-4.7	6.4	8.8	13.2	11.6	6.5	-0.2	-4.8	-16.6
	Dmax	15.0	1.1	16.1									3.9
	Dmin	0.0	0.0	0.0									0.0
1973	Precipitation	32.8	29.7	78.2	41.7	114.3	83.8	99.3	100.8	27.4	89.9	61.0	49.3
	Mean Max Daily Temp	-4.0	-8.1	3.9	9.1	14.7	22.2	24.4	25.6	18.7	13.2	1.1	-5.9
	Mean Min Daily Temp	-15.6	-19.3	-3.9	-1.7	4.4	12.9	14.1	16.4	8.9	4.7	-4.4	-13.8
	Dmax	31.1	0.0	129.8									9.4
	Dmin	1.7	0.0	17.8									0.0
1974	Precipitation	83.1	76.2	31.5	71.1	85.9	85.6	78.7	64.8	104.1	106.2	53.8	67.6
	Mean Max Daily Temp	-8.1	-9.2	-2.4	7.8	12.8	20.9	24.2	23.2	15.1	8.0	2.5	-2.1
	Mean Min Daily Temp	-16.9	-20.1	-12.1	-2.6	3.2	10.9	13.4	12.5	5.1	-0.3	-3.6	-9.0
	Dmax	17.8	1.1	27.2									12.2
	Dmin	0.0	0.0	0.0									0.0
1975	Precipitation	116.8	53.1	65.3	33.5	71.9	55.1	27.2	21.8	75.9	85.1	109.7	43.9
	Mean Max Daily Temp	-5.9	-5.3	-1.9	7.1	21.0	23.2	26.7	24.9	15.7	11.4	6.4	-5.7
	Mean Min Daily Temp	-16.7	-14.2	-12.8	-4.8	9.1	12.4	14.4	13.2	6.5	2.7	-1.4	-14.3
	Dmax	8.9	13.9	26.1									26.1
	Dmin	0.0	0.0	0.6									0.0
1976	Precipitation	52.8	85.6	101.3	17.5	95.3	44.2	48.8	75.2	158.8	57.4	44.5	29.2
	Mean Max Daily Temp	-9.4	-3.4	0.4	10.1	15.4	25.2	24.2	24.2	17.4	7.8	-0.8	-9.3
	Mean Min Daily Temp	-22.3	15.6	-10.7	-1.1	3.9	12.7	13.1	11.8	6.1	-0.4	-7.3	-21.8
	Dmax	0.6	17.8	19.5									0.0
	Dmin	0.0	0.0	5.0									0.0
1977	Precipitation	50.9	64.5	71.2	36.2	22.1	47.5	156.7	101.8	125.9	58.4	96.9	86.8
	Mean Max Daily Temp	-11.8	-4.9	4.9	10.8	21.6	21.9	25.1	20.8	16.7	10.5	3.2	-6.7
	Mean Min Daily Temp	-21.4	-13.0	-5.5	-1.6	7.2	10.5	13.6	10.5	8.4	1.0	-3.4	-13.3
	Dmax	0.0	10.0	158.6									6.1
	Dmin	0.0	0.0	8.4									0.0
1978	Precipitation	83.6	14.3	42.4	51.1	70.7	72.2	92.3	157.8	160.7	68.8	60.6	100.5
	Mean Max Daily Temp	-11.1	-8.0	-1.4	5.6	20.2	20.8	23.9	22.8	15.6	8.8	2.2	-6.1
	Mean Min Daily Temp	-19.5	-17.8	-13.2	-4.1	7.3	8.4	12.6	12.0	6.3	0.4	-6.5	-14.9
	Dmax	0.0	0.0	35.8									1.4
	Dmin	0.0	0.0	0.0									0.0
1979	Precipitation	68.0	36.0	105.1	176.8	48.7	79.1	80.9	97.5	54.0	96.7	100.1	66.1
	Mean Max Daily Temp	-10.8	-11.5	1.3	6.8	15.9	21.8	25.3	20.7	18.0	8.3	2.7	-2.4
	Mean Min Daily Temp	-18.7	-22.7	-8.9	-2.1	5.1	10.1	13.7	11.2	6.7	1.6	-4.0	-11.0
	Dmax	0.1	10.3	99.9									32.3
	Dmin	0.0	0.0	1.7									0.3
1980	Precipitation	96.1	30.7	78.7	111.4	61.9	64.4	68.0	100.0	148.1	67.0	68.0	56.5
	Mean Max Daily Temp	-7.2	-8.2	-1.4	8.2	18.7	18.9	24.7	24.0	15.6	6.8	1.0	-8.8
	Mean Min Daily Temp	-16.1	-18.4	-11.3	-0.7	6.1	7.8	13.1	14.1	6.1	-1.2	-6.2	-20.5
	Dmax	9.8	1.1	36.4									0.7
	Dmin	0.0	0.0	0.9									0.0
1981	Precipitation	16.0	83.6	37.8	130.5	57.0	112.2	30.8	68.7	177.1	109.4	36.9	41.2
	Mean Max Daily Temp	-10.6	-2.2	0.8	9.5	15.8	20.5	26.1	24.0	15.3	8.0	3.8	-4.3
	Mean Min Daily Temp	-20.5	-11.5	-7.7	-1.6	4.0	10.0	13.6	13.2	7.0	-0.1	-4.1	-11.1
	Dmax	0.0	47.4	79.4									7.3
	Dmin	0.0	0.9	5.5									0.0

APPENDIX C
DETAILS OF DISCHARGE CALCULATIONS FOR THE ROUTING SUBMODEL

APPENDIX C

DETAILS OF DISCHARGE CALCULATIONS
FOR THE ROUTING MODEL

The subbasin discharge must be defined as belonging to one of the following classes

- no regulation
- regulation subject to a rating curve
- regulation subject to rule curve operation (or historic lake levels).

The subbasin continuity is schematized in Figure C-1 for each of these three categories. The following subsections define these regulating classes in terms of subbasin continuity.

C1 - NO REGULATION

Where no regulation exists, the discharge from the subbasin is simply the sum of subbasin runoff, upstream subbasin discharge and external inflow. The subbasin discharge is written as

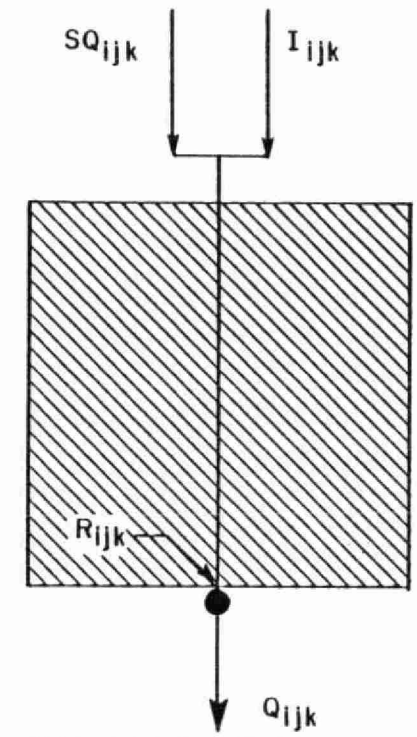
$$Q_{ijk} = R_{ijk} + SQ_{ijk} + I_{ijk} \qquad (C1)$$

where

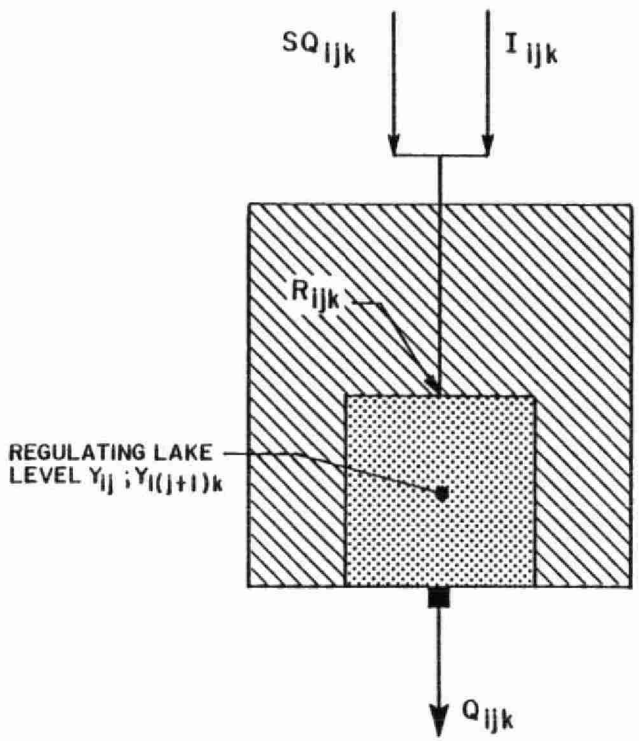
Q_{ijk} - discharge (m^3/s) from subbasin k

R_{ijk} - subbasin runoff (m^3/s) from subbasin k

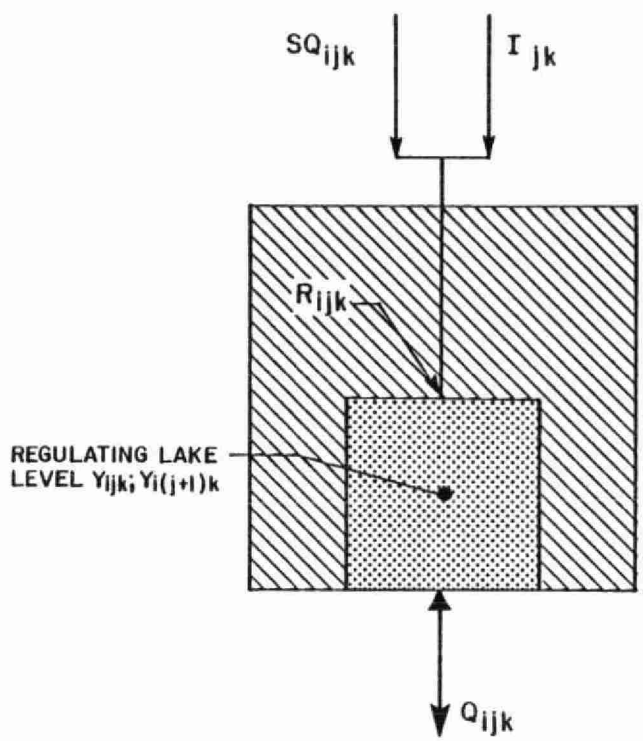
SQ_{ijk} - summation of upstream subbasin discharges (m^3/s) which flow directly into subbasin k



SUB-BASIN WITH NO REGULATION



SUB-BASIN WITH REGULATION
SUBJECT TO RATING CURVE



SUB-BASIN WITH IMPOSED
REGULATION

LEGEND

- SUB-BASIN
- REGULATING LAKE
- ● NO REGULATION
- ■ NATURAL REGULATION (RATING CURVE)
- ▲ IMPOSED REGULATION (RULE CURVE, ACTUAL LAKE LEVELS)

Y_{ijk} ELEVATION OF REGULATING LAKE AT START OF MONTH J (SUB-BASIN K)

$Y_{I(J+1)k}$ ELEVATION OF REGULATING LAKE AT END OF MONTH J (SUB-BASIN K)

Q_{ijk} DISCHARGE FROM SUB-BASIN K IN YEAR I, MONTH J

RI_{jk} TOTAL RUNOFF IN SUB-BASIN K

SQ_{ijk} SUM OF UPSTREAM SUB-BASIN DISCHARGES WHICH DISCHARGE DIRECTLY INTO SUB-BASIN K

I_{ijk} EXTERNAL INFLOW INTO SUB-BASIN K

FIG. C-1

ONTARIO MINISTRY OF THE ENVIRONMENT
STATISTICAL CHAIN-OF-LAKE-MODEL

SCHEMATIC OF SUB-BASIN CONTINUITY

ACRES

I_{ijk} - external inflow (m^3/s) to subbasin k

i - subscript denoting year

j - subscript denoting month

k - subscript denoting subbasin.

The external inflow (I_{ijk}) is user supplied and represents inflow into the drainage basin. If concurrent drainage basins are modeled separately for one watershed, then the discharge from the upstream drainage basin becomes the external inflow to the subbasin immediately downstream.

C2 - REGULATION SUBJECT TO A RATING CURVE

The discharge may be regulated by a natural control or by a man-made structure at the outlet of the regulating lake. The discharge is represented by a rating curve of the form

$$Q_{ijk} = a\left(\frac{Y_{ijk} + Y_{i(j+1)k}}{2}\right)^b \qquad (C2)$$

where

Y_{ijk} - elevation of the regulating lake (with respect to the elevation of the weir crest) at the start of month j

$Y_{i(j+1)k}$ - elevation of the regulating lake at the end of month j

a, b - coefficients.

The subbasin continuity expression is written as

$$Q_{ijk} = (Y_{ijk} - Y_{i(j+1)k} - e_{jk} + PR_{ijk})(AREGL_k)(f) + R_{ijk} + SQ_{ijk} + I_{ijk} \qquad (C3)$$

where

e_{jk} - evaporation coefficient (m/month) for subbasin k

PR_{ijk} - actual precipitation (m/month) which falls on the regulating lake in subbasin k

$AREGL_k$ - area of regulating lake (km^2) for subbasin K

f - conversion factor (to convert MCM/month to m^3/s).

To calculate the subbasin discharge (Q_{ijk}), Equations C2 and C3 are solved simultaneously. Because of the nonlinear relationship of discharge to lake elevation, the chain-of-lakes model sequentially calculates the subbasin discharges for ten equal time segments within the monthly period. The model outputs only the average discharge over the month and the month-end lake elevation.

C3 - REGULATION SUBJECT TO RULE CURVE OPERATION (OR HISTORIC LAKE LEVELS)

To describe the imposed regulation, the user can supply either

- rule curves which define the elevation of the regulating lake as a function of the calendar date. The chain-of-lakes model adjusts the user-supplied rule curve so that it corresponds to month-end calendar dates.

- historic lake levels for each month and year of the simulation period.

Any arbitrary datum may be used in the definition of the rule curves or the historic lake levels.

Given the above imposed regulation, the continuity expression is given as

$$Q_{ijk} = (Y_{ijk} - Y_{i(j+1)k} - e_{jk} + PR_{ijk})(AREGL_k)(f) + R_{ijk} + SQ_{ijk} + I_{ijk} \quad (C4)$$

The elevations of the regulating lake [Y_{ijk}, $Y_{i(j+1)k}$] in Equation C4 are defined by the rule curves or by historic lake levels. For operative purposes, the model treats historic lake levels as if they were rule curve values.

If the discharge (Q_{ijk}), as calculated from Equation C4, is less than zero, then the lake level [$Y_{i(j+1)k}$] cannot be achieved, therefore

$$Q_{ijk} = 0$$

and

$$Y_{i(j+1)k} = Y_{ijk} - e_{jk} + PR_{ijk} + \frac{(R_{ijk} + SQ_{ijk} + I_{ijk})}{(AREGL)_k(f)} \quad (C5)$$

APPENDIX D
DETAILS OF CALIBRATION PROCEDURES

APPENDIX D

DETAILS OF CALIBRATION PROCEDURES

The following two calibration techniques are available in the chain-of-lakes model

(i) Historic replication of a specific basin discharge record.

(ii) Improvement of the runoff prediction equations for a specific data record.

These calibration techniques are described in the following subsections.

D1 - HISTORIC REPLICATION

When calibrating so that the historic basin discharges are replicated, the model adjusts the subbasin runoff on a month-by-month basis so that the calculated basin discharge is equal to measured basin discharge. This calibration method is event specific and, therefore, is limited to only those months where historic discharge data is available. Given the requirement to replicate the historic basin discharge, the model distributes the basin-wide calibration into the individual subbasins by prorating the subbasin runoff, as calculated from the runoff prediction equations.

To replicate the historic basin discharge, the following steps are followed to determine the subbasin runoff.

1 - On a month-by-month basis, compute the runoff for each subbasin by using the runoff prediction equations.

The subbasin runoff is represented as R_{ijk}^{n}, where the superscript n denotes the iteration (in this case n=0) and i = year, j = month, k = subbasin.

2 - Route the subbasin runoff (R_{ijk}^{n}) throughout the drainage network. Determine the calculated basin discharge (Q_{ijm}^{n}) where m represents the furthest downstream subbasin.

3 - Increment the iteration counter (n) by 1. Given the measured basin discharge (QM_{ij}), the total measured basin runoff is approximated by backrouting the measured basin discharge with respect to net changes in lake storage throughout the basin. The total measured basin runoff is calculated as

$$RM_{ij} = QM_{ij} - \left(Q_{ijm}^{n-1} - \sum_{k=1}^{N} R_{ijk}^{n-1} \right)$$

For all, i = 1, 2,...NYRS and j = 1, 2,...12 months

where N = the total number of subbasins contoured in the drainage network.

NYRS = the total number of years in the simulation period

The quantity in brackets in the above equation is the net change in lake storage throughout the basin.

4 - Compute the ratio:

$$RATIO = \frac{RM_{ij}}{\sum_{k=1}^{N} R_{ijk}}$$

5 - Use the ratio calculated in Step 4 to adjust the subbasin runoff

$$R_{ijk}^{n} = (RATIO)(R_{ijk}^{o})$$

For all, k = 1, 2,...N subbasins

6 - Route the subbasin runoff (R_{ijk}^{n}) throughout the drainage network. Determine the calculated basin discharge (Q_{ijm}^{n}).

7 - If additional iteration is necessary, repeat Steps 3 to 6 inclusive.

The calculated basin discharge (Q_{ijm}^{n}) will implicitly converge toward a value equal to the measured basin discharge (QM_{ij}). More than one iteration is required only in those cases in which the total volume of stored water varies from iteration to iteration.

D2 - IMPROVEMENT TO RUNOFF PREDICTION EQUATIONS

Instead of the month by month replication of historic inflows, the improvement to the runoff prediction equations has a broader basis for application. With a given measured record for basin discharge, revised regression coefficients are derived to make the runoff prediction equations basin specific. Extrapolation of the data can then be made by utilizing these revised regression coefficients in subsequent runs of the chain-of-lakes model.

To determine the revised coefficients, this calibration technique is performed as a postsimulation exercise. If the simulation period consists of (NYRS) calendar years, then for each month there are (NYRS) pairs of calculated and measured basin discharges. The measured basin discharges form the basis for calculation of the revised regression coefficients. Linear regression analysis is used to estimate these coefficients for each month. It is important to note that the revised regression coefficients are only applicable for the derivation of total basin runoff. The basin-wide calibration must then be distributed to the subbasin level. Working on a month-by-month basis, the distribution used herein is similar to that used in the historic replication technique.

Before a detailed description of the calibration technique is given, it is necessary to review the general form of the runoff prediction equations.

The general form of the runoff prediction equations are as follows.

<u>April to November</u>

$$R_{ijk} = a_1 + A_{B_k}(a_2 P_{ijk} + a_3) + A_{L_k}(a_4 P_{ijk} + a_5) + a_6 A_{s_k} \qquad \text{(D1)}$$

where

R_{ijk} - subbasin runoff (m^3/s)

A_{B_k} - area (km^2) of the subbasin k

A_{L_k} - area (km^2) of lakes in subbasin k

A_{s_k} - area (km^2) of swamps in subbasin k

P_{ijk} - monthly precipitation (m) computed with respect to runoff prediction

$a_1 - a_6$ - coefficients (vary from month to month)

i - subscript denoting year

j - subscript denoting month

k - subscript denoting subbasin

<u>December to March</u>

$$R_{ijk} = a_1 + a_2 A_{L_k} + a_3 A_{B_k} + P_{ijk}(a_4 + a_5 D_{ijk}) \qquad (D2)$$

where

D_{ijk} - degree days (°C) above freezing

Equation D1 can be simplified to

$$R_{ijk} = \alpha_{1k} + \beta_{1k} P_{ijk} \qquad (D3)$$

and Equation D2 can be simplified to

$$R_{ijk} = \alpha_{2k} + \beta_{2k} P_{ijk} + \gamma_{2k} P_{ijk} D_{ijk} \qquad (D4)$$

Equations D1, D2, D3 and D4 are similar to Equations 12, 13, 14 and 15 of Section 3.4

Note that the above equations are linear with respect to variables P_{ijk} and $P_{ijk}\, D_{ijk}$. By extension, the total basin runoff $\sum_{k=1}^{N} R_{ijk}$ is also a function of P and (P D).

Let the furthest downstream subbasin be denoted by the subscript m. Then the total basin runoff can be represented as either

$$\sum_{k=1}^{N} R_{ijk} = A_1 + B_1 P_{ijm} \qquad (D5)$$

or

$$\sum_{k=1}^{N} R_{ijk} = A_2 + B_2 P_{ijm} + C_2 P_{ijm} D_{ijm} \qquad (D6)$$

for the summer and winter months respectively.

If the parameters P_{ijm} and $P_{ijm}D_{ijm}$ are applicable to the entire basin then

$$A_1 = \sum_{k=1}^{N} \alpha_{1k} \qquad A_2 = \sum_{k=1}^{N} \alpha_{2k}$$

$$B_1 = \sum_{k=1}^{N} \beta_{1k} \qquad B_2 = \sum_{k=1}^{N} \beta_{2k}$$

$$C_2 = \sum_{k=1}^{N} \gamma_{3k}$$

A basic premise of the chain-of-lakes model is the limited data base. In general, Equations D5 and D6 adequately represent the total basin runoff. Given the total measured basin runoff (RM_{ij}), then the regression equations

$$RM_{ij} = A'_1 + B'_1 P_{ijm} \qquad (D7)$$

and

$$RM_{ij} = A'_2 + B'_2 P_{ijm} + C'_2 P_{ijm} D_{ijm} \qquad (D8)$$

can be derived. Coefficients A'_1, A'_2, B'_1, B'_2, and C'_2 make the model basin specific.

The following steps outline the methodology of this calibration technique.

1 - For the entire simulation period of (NYRS) calendar years, compute the runoff for each subbasin by using the runoff prediction equations.

The subbasin runoff is represented as R_{ijk}^{n}, where the superscript n refers to the iteration number (in this case n = 0).

2 - For the entire simulation period, route the subbasin runoff (R_{ijk}^{n}) throughout the drainage network. Determine the calculated basin discharge (Q_{ijm}^{n}), where m represents the furthest downstream subbasin.

3 - Increment the iteration counter (n) by 1. Given the measured basin discharge (QM_{ij}), the total measured basin runoff is approximated by backrouting the measured basin discharge with respect to changes in lake storage and for net evaporation throughout the basin. The total basin runoff is calculated as

$$RM_{ij} = QM_{ij} - \left(Q_{ijm}^{n-1} - \sum_{k=1}^{N} R_{ijk}^{n-1} \right)$$

4 - For each of the 12 months, determine by linear regression the coefficients A_1', A_2', B_1', B_2' and C_2' of Equations D7 and D8.

5 - On a month-by-month basis, calculate the estimate of total basin runoff ($\hat{RM}_{ij}$) by using the regression equations as derived in Step 4.

6 - On a month-by-month basis, compute the ratio

$$RATIO = \frac{\hat{RM}_{ij}}{\sum_{k=1}^{N} R_{ijk}^{o}}$$

7 - On a month-by-month basis, use the ratio (calculated in Step 6) to adjust the subbasin runoff

$$R_{ijk}^{n} = (RATIO)(R_{ijk}^{o})$$

For all, k = 1, 2,...N subbasins.

8 - Route the subbasin runoff (R_{ijk}^{n}) throughout the drainage network. Determine the calculated basin discharge (Q_{ijm}^{n}).

9 - If additional iteration is necessary, repeat Steps 3 to 8.

The derivation of the revised regression coefficients (Step 4) is a postsimulation analysis. Subsequent steps in the methodology are performed on a monthly basis. Using the revised regression coefficients, an estimate of basin runoff is determined. The estimated basin runoff is then compared with the calculated basin runoff (iteration n = 0). The ratio so calculated is then used to distribute runoff throughout the subbasins. At this stage, this method is similar to that used in the historic replication technique.

The monthly average for total basin discharge, as computed in this calibration technique, will implicitly converge toward the corresponding average for measured discharge. This convergence is inherent because the linear regression analysis will replicate the mean of the measured runoff. Basin discharge is equal to the sum of basin runoff and the change in volume of stored water. More than one iteration is required only for those cases in which the total volume of stored water varies from iteration to iteration.

The results of the calibration (A_1', A_2', B_1', B_2', and C_2') can be read into the program and used in subsequent data extension runs. For application of the calibration results to data extension, omit Steps 3, 4 and 9 from the above methodology.

APPENDIX E
FILE SPECIFICATIONS AND DATA INPUT REQUIREMENTS

APPENDIX E

FILE SPECIFICATIONS AND DATA INOUT REQUIREMENTS

The data input to the chain-of-lakes model is described herein. Note that all data input is unformatted.

E1 - CHAIN-OF-LAKES MODEL: FILE STRUCTURE

Within the chain-of-lakes computer program, the following unit numbers are accessed.

Unit Number	File Type	Description
5	input	input control data
6	output	output listing
8	input	temperature data for runoff calculations
9	input	precipitation data for runoff calculations
10	input	monthly precipitation data
11	input	measured discharge data
12	input	measured month-end lake levels
13	input	external inflow data
14	output	basin discharge data; can be used in the chain-of-lakes model as external inflow data for the consideration of downstream basins
15	output	subbasin discharge data, which replaces the data output of the 'HYDRO' module of the Serpent River model

E2 - INPUT CONTROL DATA

1 - TITLE 1 - enter 3 lines of title description

2 - TITLE 2

3 - TITLE 3

4 - NYR1, MTH1, NYR2, MTH2
where NYR1 - start year of simulation
MTH1 - initial calendar month for simulation (e.g., for January start month, set MTH1 = 1)
NYR2 - final year of simulation
MTH2 - final calendar month for simulation (e.g., for December termination, set MTH2 = 12).

5 - IPRT1, IPRT2, IPRT3
where IPRT1 - print flag to obtain the monthly summary output; can be used to check subbasin continuity
= 0 do not print monthly summaries
= 1 print monthly summary output
IPRT2 - print flag to obtain the subbasin discharge summary output
= 0 do not print subbasin discharge summaries
= 1 print subbasin discharge summary output
IPRT3 - print flag to obtain the month-end lake level summary output
= 0 do not print month-end lake level summaries
= 1 print month-end lake level summaries

6 - IADJ1, IADJ2

where IADJ1 - flag to indicate the calibration such that there is a month-by-month historical replication of basin discharges (see Section 5.1)

= 0 do not adjust data

≥ 0 adjust data, IADJI represents the number of iterations to be performed

IADJ2 - flag to indicate the calibration techniques to improve the runoff prediction equations (see Section 5.2)

= 0 do not adjust data

≥ 0 adjust data, IADJ2 represents the number of iterations to be performed

NOTE: IADJ1 and IADJ2 cannot both be greater than zero.

7 - NBASIN

where NBASIN - the total number of subbasins contained in the watershed

REPEAT CARD GROUPS 8 - 18 INCLUSIVE FOR (NBASIN) SUBBASINS

8 - NAME

where NAME - subbasin name or identifier (≤8 characters)

9 - NODE, NREG, NINF, NDIS

where NODE - the node number used to represent this subbasin

NREG - flag to indicate the type of discharge regulation for this basin (refer to Section 4.2.2)

= 0 no regulation

= 1 regulation by means of a control point at the outlet of the regulating lake (discharge calculation follows a weir discharge equation ($Q = ay^b$)

= 2 imposed regulation by means of rule curves or measured lake levels

NINF - flag to indicate whether external inflow data (see E8) is to be input for this subbasin

= 0 do not input data

= 1 input external inflow data for this subbasin

NDIS - flag to indicate whether measured discharge data (See E6) is to be input for this subbasin

= 0 do not input data

= 1 input measured discharge data for this subbasin

10 - NBDWN, NTIES, [NBUP(J), J = 1,NTIES]

where NBDWN - the node number representing the subbasin which is immediately downstream from the current subbasin

= 0 if there is no downstream basin (i.e., the discharge from this subbasin is the outlet from the watershed

NOTE: only 1 watershed should be considered in each run of the chain-of-lakes model

NTIES - the total number of subbasins which directly discharge into the current subbasin

= 0 if there is no upstream subbasin

NBUP - the node number representing the subbasins which discharge directly into the current subbasin

11 - AB, AL, AS

where AB - area of subbasin (km^2) for use in the runoff prediction equations

AL - area of lake within subbasin (km^2) for use in the runoff prediction equations

AS - area of swamps within subbasin (km^2) for use in the runoff prediction equations

SKIP CARD GROUPS 12 - 17 INCLUSIVE IF NREG = 0
INPUT CARD GROUP 12 IF NREG = 1
SKIP CARD GROUP 12 IF NREG = 2

12 - AREGL, Y(1), A, B

where AREGL - area of regulating lake (km^2) for this subbasin

Y(1) - initial lake level (m) for this regulating lake with respect to weir crest elevation

A, B - coefficients for discharge calculation, the discharge Q(I) in month 1 is calculated as

$$Q(I) = A\left(\frac{Y(I) + Y(I+1)}{2}\right)^B \qquad (m^3/s)$$

where Y(I) and Y(I+1) are the initial and final regulating lake elvations in month I

SKIP CARD GROUPS 13 - 17 INCLUSIVE IF NREG = 1
INPUT CARD GROUPS 13 - 17 INCLUSIVE IF NREG = 2

13 - AREGL

where AREGL - area of regulating lake (km^2) for this subbasin

14 - IRC

where IRC - flag to indicate whether rule curves or measurd lake levels are read in to describe the imposed regulation for this subbasin

= 0 input rule curve data

= 1 input measured lake levels (see E7)

SKIP CARD GROUPS 15 - 17 INCLUSIVE IF IRC = 1

15 - NRCPTS

where NRCPTS - the number of data points which are used to describe the rule curve for the regulating lake of the current subbasin

16 - [RCDAYS (1), I = 1, NRCPTS]

where RCDAYS - are the cumulative calendar days (1-365; Jan 1 = 1) which corresponds to the input rule curve elevations (RCCRV)

17 - [RCCRV(I), I = 1, NRCPTS]

where RCCRV - are the regulating lake elevations (m) which define the rule curve with respect to the calendar days (RCDAYS)

NOTE: The chain-of-lakes program interpolates rule curves for the month end calendar dates.

18 - IEQN

where IEQN - flag to indicate type of runoff prediction equation

= 0 historic sequential runoff equations

= 1 ranked runoff equations

REPEAT CARD GROUP 19 FOR (12) MONTHS

19 - [a(J), J = 1,6]

where a - coefficients for monthly regression equations which are used to describe basin runoff [called C(J) in Fortran code]

- see Tables 2 and 3

20 - NEVAP

where NEVAP - the total number of evaporation records to be input

REPEAT CARD GROUPS 21 and 22 FOR (NEVAP) RECORDS

21 - NEV, [NEVP(I), I = 1, NEV]

where NEV - the total number of subbasins for which this evaporation data is applicable

NEVP - the node numbers of subbasins for which this evaporation data is used in the calculation of evaporation loss

22 - [EVAP(J), J = 1, 12]

where EVAP - monthly evaporation coefficients (m/month)

- to calculate the evaporation loss in a given month, the evaporation coefficient is multiplied by the area of the regulating lake for those subbasins which have regulation control
- EVAP(1) corresponds to the January evaporation coefficient

23 - ICOEFF

where ICOEFF - flag to indicate whether the linear regression coefficients (A_1', A_2', B_1', B_2', C_2') are to be input by the user (as derived by the calibration technique to improve the runoff prediction equations)

- refer to Section D2 in Appendix D
- = 0 do not input regression coefficients
- = 1 input regression coefficients

INPUT CARD GROUPS 24, 25 and 26 IF ICOEFF = 1

24 - [A2(I), I = 1,3; A1(I), I = 4, 11; A2(12)]

where A1 and A2 are monthly regression coefficients input by the user to adjust the runoff

- A1 and A2 are equivalent to A_1' and A_2' in Equations D7 and D8

25 - [B2(I), I = 1, 3; B1 (I) = 4, 11; B2 (12)]

where B1 and B2 are monthly regression coefficients input by the user to adjust the runoff equations

- B1 and B2 are equivalent to B_1' and B_2' in Equations D7 and D8

26 - [C2(I), I = 1, 3; 0, 0, 0, 0, 0, 0, 0, 0,; C2(12)]

where C2 - monthly regression coefficients input by the user to adjust the runoff equations

- C2 is equivalent to C_2' in Equation D8

E3 - TEMPERATURE DATA FOR RUNOFF CALCULATIONS

The temperature data file is set up so that it is directly compatible with the runoff regression equations. If the regression analysis has determined that runoff in a particular month is dependent on temperature records for the current and previous months, then the input temperature data consists of the aggregate of the temperature records for those months.

1 - NTEMP

where NTEMP - the total number of separate temperature data records to be input

REPEAT CARD GROUPS 2, 3 AND 4 for (NTEMP) RECORDS

2 - NBT, [NBTMP(J), J = 1, NBT]

where NBT - the total number of subbasins for which this temperature data set is applicable

NBTMP - the node numbers of those subbasins which utilize this temperature data set in the regression equations of runoff

3 - NYRS

where NYRS - the total number of years of monthly temperature data to be input for this particular temperature record

REPEAT CARD GROUP 4 FOR (NYRS) YEARS

4 - NYEAR, [X(J), J = 1, 12]

where NYEAR - calendar year

X(J) - monthly temperature data (°C degree days above freezing/month) which is used directly in the regression equations to determine subbasin runoff for a particular month

- X(1) corresponds to January data

E4 - PRECIPITATION DATA FOR RUNOFF CALCULATIONS

The precipitation data file is set up so that it is directly compatible with the runoff regression equations. If the regression analysis has determined that runoff in a particular month is dependent on the precipitation in the current and previous months, then the input precipitation data consists of the aggregate of the precipitation values for those months.

1 - NPPT

where NPPT - the total number of separate precipitation records to be input

REPEAT CARD GROUPS 2, 3 and 4 FOR (NPPT) RECORDS

2 - NBPT, [NBPPT(J), J = 1, NBPT]

where NBPT - the total number of subbasins for which this precipitation data set is applicable

NBPPT - the node numbers of those subbasins which utilize this precipitation data set in the regression equations of runoff

3 - NYRS

where NYRS - the total number of years of monthly precipitation data to be input for this particular precipitation record

REPEAT CARD GROUP 4 FOR (NYRS) YEARS

4 - NYEAR, [X(J), J= 1, 12]

where NYEAR - calendar year

X(J) - monthly precipitation data (m/month) which is used in regression equations to determine subbasin runoff for a particular month

- X(1) corresponds to January data

E5 - MONTHLY PRECIPITATION DATA

The monthly precipitation data in this file is equivalent to the monthly historic record.

1 - MPT

where MPT - the total number of separate precipitation data records to be input

REPEAT CARD GROUPS 2, 3 AND 4 FOR (MPT) RECORDS

2 - MBPT, [MBPPT(J), J = 1, MBPT]

where MBPT - the total number of subbasins for which this precipitation data set is applicable

MBPPT - the node numbers of those subbasins which utilize this precipitation data in the water continuity calculations

3 - NYRS

where NYRS - the total number of years of monthly precipitation data to be input for this particular precipitation record

REPEAT CARD GROUP 4 for (NYRS) YEARS

4 - NYEAR, [X(J), J 1, 12]

where NYEAR - calendar year

X(J) - monthly precipitation data (m/month) which is used in the water continuity calculations for the regulating lake in a particular subbasin

- X(1) corresponds to January data

E6 - MEASURED DISCHARGE DATA

For any subbasin in the drainage network, measured discharge data can be input and the chain-of-lakes model will give the comparative statistics between calculated and measured discharges. Calibration, based on the measured discharge data, is only performed for the farthest downstream subbasin (defined by variable NBDWN = 0; See E2). The calibration technique is dependent on the value of parameters IADJ1 and IADJ2 (See E2).

REPEAT CARD GROUPS 1 and 2 FOR EACH SUBBASIN IN WHICH VARIABLE NDIS = 1 (See E2)

1 - NC, NYRS

where NC - the node number representing the subbasin for which the following historic discharge data is applicable

NYRS - the total number of years of discharge data for this subbasin

REPEAT CARD GROUP 2 FOR (NYRS) YEARS

2 - NYEAR, [X(J), J = 1, 12]
    where NYEAR - calendar year
          X(J) - monthly discharge (m^3/s)
                 - X(1) corresponds to January data

E7 - MEASURED MONTH-END LAKE LEVELS

Within the chain-of-lakes model, the discharge from each subbasin may be described by the following

- unregulated
- regulation as defined by a discharge weir or other natural or man-made control structure
- imposed regulation by either rule curves or the measured lake levels.

This data set contains the measured lake levels for those subbasins with imposed regulation.

REPEAT CARD GROUPS 1, 2 AND 3 FOR EACH SUBBASIN IN WHICH VARIABLES NREG = 2 AND IRC = 1

1 - NCODE, NYRS
    where NCODE - the node number representing the subbasin for which the following lake level data is applicable
          NYRS - the total number of years of lake level data to be input for this subbasin

REPEAT CARD GROUPS 2 AND 3 FOR (NYRS) YEARS

2 - NYEAR, ELVI
    where NYEAR - calendar year
          ELVI - the January 1 lake elevation (m) for the regulated lake for this subbasin

3 - [X(J), J = 1, 12]
    where X(J) - month end lake elevations (m) for the regulated lake for this subbasin
               - X(1) corresponds to the January month-end lake elevations

E8 - EXTERNAL INFLOW DATA

An external inflow can be applied to any subbasin. This data could represent the channel inflow to a subbasin which is gauged or has previously been calculated by the chain-of-lakes model.

REPEAT CARD GROUPS 1 AND 2 FOR EACH SUBBASIN IF VARIALE NINF = 1 (See E2)

1 - NC, NYRS
    where NC - the node number representing the subbasin into which this external inflow is input
          NYRS - the total number of years of inflow data to be input for this particular basin

REPEAT CARD GROUP 2 FOR (NYRS) YEARS

2 - NYEAR, [X(J), J=1, 12]
    where NYEAR - calendar year
          X(J) - monthly inflow (m^3/s) which is used in the monthly water continuity calculations for the particular subbasin
               - X(1) corresponds to January data

APPENDIX F
EXAMPLE RUN - HISTORICAL REPLICATION
SOUTH BRANCH MUSKOKA RIVER

APPENDIX F

EXAMPLE RUN -
HISTORICAL REPLICATION
SOUTH BRANCH MUSKOKA RIVER

In this appendix the historical replication of the South Branch Muskoka River for the period 1975 to 1980 is presented as a sample run.

All input and output files are included. Tables F-1 to F-6 are the input files while Tables F-7 to F-9 are the output files.

F-1 - Control data file for the historical replication at Baysville

F-2 - Temperature data (celcius) with respect to runoff calculations

F-3 - Precipitation data (M/month) with respect to runoff calculations

F-4 - Precipitation data (M/month) as recorded

F-5 - Measured basin discharge (m^3/s)

F-6 - Historical month-end reservoir levels (m)

F-7 - Output file for historical replication at Baysville. Individual monthly summaries are only included for January and February 1975

F-8 - Output data file to be used as input to the Serpent River Model

F-9 - Summary of calculated discharges from basin, to be used as an input file for the downstream basin

TABLE F-1 CONTROL DATA FILE FOR
HISTORICAL REPLICATION AT BAYSVILLE

```
SOUTH BRANCH OF THE MUSKOKA RIVER - DETERMINISTIC RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980
1975 1 1980 12
1 1 1
3 0
6
BURNT
1 2 0 0
2 0 0
  49.45     3.209     1.523
  9.60
0
5
1  120  248  288  365
29.87 30.78 30.78 29.26 29.87
JOE
2 2 0 0
5 1 1
  53.00     4.293     2.507
  5.80
0
9
1  46  74  95  120  151  258  288  365
421.35 421.35 421.00 421.00 421.90 421.85
421.85 421.55 421.55
KAWA
3 2 0 0
6 0 0
 354.80    33.614     4.276
 31.80
1
RAGGED
4 2 0 0
5 0 0
  64.15     6.858     1.257
  6.30
0
5
1  151  227  258  365
431.81 432.67 432.67 431.45 431.81
```

TABLE F-1 CONTROL DATA FILE FOR
CONT'D HISTORICAL REPLICATION AT BAYSVILLE

```
TSC
 5 2 0 0
 6 2 2 4
  142.38    10.377     3.113
  12.30
  0
  8
  1  46  74  90  120  151  258  365
  417.58 417.48 417.21 417.21 417.88 417.82
  417.82 417.58
BAY
 6 2 0 1
 0 2 5 3
 591.35    37.849    24.494
 68.40
 1
 0
 0.244  0.048  0.000  0.025  0.00066 0.000
 0.213  0.042  0.000  0.018  0.04900 0.000
 1.033 -0.039  0.0071 0.000  0.04300 0.000
-0.926  0.529  0.020  0.000 -0.267   0.262
-0.384  0.051  0.023  0.000  0.213   -0.108
 0.071  0.119  0.000  0.000  0.114   -0.074
 0.399  0.064  0.000  0.927  0.000   -0.066
 0.080  0.031  0.000  0.522  0.000   -0.038
 0.050  0.170 -0.0086 0.000 -0.022   0.000
 0.064  0.313 -0.017  0.000 -0.024   0.000
 0.060  0.296 -0.012  0.000  0.000   0.000
 0.161  0.058  0.000  0.036  0.00130 0.000
 1
 6 1 2 3 4 5 6
 0.000 0.000 0.010 0.020 0.080 0.135 0.145 0.120 0.075 0.045 0.015 0.000
 0
```

TABLE F-2 TEMPERATURE DATA (CELCIUS)
WITH RESPECT TO RUNOFF CALCULATIONS

1
6 1 2 3 4 5 6
12

1970	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.0	94.0
1971	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.0	91.0
1972	44.0	0.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.0	45.0
1973	35.0	3.0	33.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	81.0
1974	37.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	88.0
1975	29.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.0	153.
1976	24.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	47.0
1977	3.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.0	16.0
1978	9.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	21.8
1979	11.3	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0	107.
1980	24.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	49.0
1981	6.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	71.0

TABLE F-3 PRECIPITATION DATA (M/MONTH)
WITH RESPECT TO RUNOFF CALCULATIONS

1
6 1 2 3 4 5 6
12

1970	0.061	0.051	0.054	0.064	0.087	0.099	0.133	0.120	0.122	0.088	0.080	0.091
1971	0.106	0.117	0.099	0.050	0.040	0.060	0.062	0.079	0.064	0.060	0.073	0.100
1972	0.125	0.112	0.096	0.064	0.074	0.082	0.096	0.108	0.108	0.103	0.083	0.096
1973	0.124	0.086	0.083	0.068	0.081	0.169	0.137	0.118	0.057	0.061	0.077	0.092
1974	0.120	0.101	0.086	0.078	0.098	0.073	0.065	0.072	0.099	0.117	0.111	0.074
1975	0.079	0.103	0.090	0.061	0.037	0.035	0.066	0.078	0.095	0.084	0.093	0.103
1976	0.099	0.097	0.103	0.069	0.041	0.071	0.061	0.064	0.087	0.091	0.106	0.102
1977	0.099	0.082	0.074	0.038	0.040	0.043	0.032	0.083	0.102	0.106	0.126	0.129
1978	0.084	0.036	0.024	0.043	0.047	0.065	0.072	0.107	0.114	0.106	0.094	0.083
1979	0.122	0.103	0.070	0.096	0.072	0.084	0.085	0.078	0.090	0.108	0.098	0.072
1980	0.060	0.057	0.063	0.080	0.074	0.099	0.105	0.127	0.113	0.114	0.078	0.092
1981	0.103	0.064	0.065	0.078	0.730	0.087	0.069	0.119	0.140	0.160	0.104	0.068

TABLE F-4 PRECIPITATION DATA (M/MONTH)
(RECORDED MONTHLY PRECIPITATION)

```
1
6 1 2 3 4 5 6
12
1970 0.061 0.042 0.060 0.068 0.106 0.091 0.203 0.065 0.097 0.101 0.071 0.112
1971 0.100 0.134 0.064 0.036 0.045 0.075 0.067 0.094 0.031 0.053 0.086 0.114
1972 0.135 0.089 0.064 0.064 0.083 0.080 0.126 0.119 0.079 0.109 0.064 0.128
1973 0.119 0.053 0.077 0.059 0.103 0.235 0.072 0.046 0.035 0.083 0.093 0.091
1974 0.149 0.053 0.055 0.100 0.096 0.050 0.049 0.118 0.130 0.104 0.104 0.044
1975 0.114 0.092 0.066 0.036 0.057 0.053 0.087 0.093 0.105 0.035 0.101 0.106
1976 0.092 0.103 0.114 0.023 0.058 0.083 0.042 0.067 0.152 0.053 0.121 0.083
1977 0.115 0.049 0.059 0.056 0.024 0.062 0.071 0.116 0.118 0.084 0.147 0.110
1978 0.057 0.014 0.035 0.052 0.042 0.088 0.087 0.145 0.111 0.062 0.082 0.083
1979 0.161 0.044 0.091 0.028 0.116 0.053 0.086 0.094 0.090 0.138 0.088 0.055
1980 0.065 0.049 0.074 0.087 0.061 0.137 0.117 0.128 0.096 0.120 0.041 0.143
1981 0.063 0.064 0.068 0.089 0.064 0.090 0.067 0.201 0.182 0.100 0.490 0.043
```

TABLE F-5 MEASURED BASIN DISCHARGE
CUBIC METERS PER SECOND

```
6 12
1970 20.2 22.2 22.3 28.3 43.6 13.8 49.9 20.4 11.2 30.9 21.3 25.6 25.9
1971 19.7 27.3 36.1 47.5 33.6 11.1 5.18 5.79 13.2 7.55 8.36 10.4 18.7
1972 19.2 24.0 31.6 40.1 64.3 18.5 26.1 31.9 16.0 24.7 31.9 21.8 29.2
1973 29.5 40.9 57.3 58.8 34.7 31.9 17.6 16.5 15.9 16.8 10.7 25.5 29.6
1974 25.9 33.3 40.6 57.1 64.7 19.7 7.64 6.83 12.3 26.1 28.4 22.5 28.7
1975 20.3 23.1 40.1 35.5 31.5 4.62 3.38 5.06 13.8 20.1 10.4 32.0 20.0
1976 25.0 27.6 50.5 69.1 24.0 8.49 18.6 6.31 6.18 11.8 8.17 12.9 22.4
1977 15.4 13.8 41.5 38.7 13.9 4.04 3.04 3.29 14.4 33.7 24.1 27.5 19.5
1978 29.7 19.5 27.7 25.1 53.4 11.3 3.97 6.32 19.7 25.6 14.7 21.4 21.6
1979 21.5 30.7 50.1 57.4 44.7 15.8 5.09 9.52 22.1 28.3 43.1 40.1 30.6
1980 30.2 25.1 23.0 78.5 20.6 22.5 17.0 22.8 24.3 33.9 30.3 24.3 29.3
1981 20.9 37.1 52.6 31.8 22.3 13.6 5.24 3.96 61.8 37.5 14.6 16.7 26.4
```

TABLE F-6 HISTORICAL MONTH END RESERVOIR LEVELS (M)

3 6
1975 5.18
5.05 4.73 4.44 5.09 5.31 5.37 5.31 5.24 5.08 4.41 4.74 5.08
1976 5.08
4.71 4.24 4.80 5.43 5.59 5.43 5.26 5.08 4.94 4.36 4.28 4.47
1977 4.47
4.10 3.86 4.45 5.38 5.35 5.27 5.21 5.21 4.94 4.65 5.12 5.35
1978 5.35
4.73 4.22 3.72 5.37 5.49 5.61 5.53 5.41 5.06 4.68 4.89 5.09
1979 5.09
5.06 4.53 4.63 5.59 5.61 5.58 5.49 5.44 4.92 4.89 4.92 4.79
1980 4.79
4.73 4.27 4.77 5.49 5.47 5.72 5.72 5.31 5.12 4.86 5.02 5.05
6 8
1973 5.18
5.21 4.87 4.95 5.18 5.19 5.28 5.22 5.10 5.20 5.04 5.23 5.18
1974 5.18
5.17 4.92 4.25 5.28 5.13 5.16 5.10 5.19 5.19 5.13 5.22 5.06
1975 5.06
5.07 4.99 4.40 4.88 5.13 5.18 5.22 5.22 5.21 5.16 5.21 5.16
1976 5.16
5.03 4.82 4.81 5.18 5.14 5.24 5.17 5.16 5.21 5.19 5.18 5.08
1977 5.08
4.92 4.81 4.66 5.25 5.23 5.22 5.19 5.25 5.27 5.14 5.23 5.13
1978 5.13
4.89 4.79 4.40 5.21 5.19 5.16 5.18 5.27 5.21 5.16 5.24 5.18
1979 5.18
5.16 4.77 4.68 5.29 5.24 4.88 5.22 5.30 5.14 5.20 5.30 5.18
1980 5.18
5.05 4.82 4.77 5.13 5.19 5.24 5.32 5.25 5.30 5.18 5.19 5.10

TABLE F-7 OUTPUT FILE FOR HISTORIC REPLICATION AT BAYSVILLE (PAGES F-8 TO F-36)

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

SIMULATION CONTROL DATA

START - YEAR = 1975
MONTH = 1
END - YEAR = 1980
MONTH = 12

IPRT1 = 1 : PRINT MONTHLY SUMMARY

IPRT2 = 1 : PRINT BASIN DISCHARGE SUMMARY

IPRT3 = 1 : PRINT LAKE LEVEL SUMMARY

IADJ1 = 3 : NUMBER OF ITERATIONS FOR MONTH-BY-MONTH BASIN DISCHARGE ADJUSTMENT
IADJ2 = 0 : NUMBER OF ITERATIONS FOR LINEAR REGRESSION ADJUSTMENT

NUMBER OF BASINS = 6

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN BURNT - NODE NUMBER 1

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 0

DOWNSTREAM BASIN = 2
NUMBER OF UPSTREAM INFLOWS = 0

AREA OF BASIN = 49.4500 KM**2
AREA OF LAKES = 3.2090 KM**2
AREA OF SWAMPS = 1.5230 KM**2

AREA OF REGULATED LAKE = 9.6000 KM**2

RULE CURVE FOR LAKE OPERATION (M)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
30.099	30.314	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.624	29.870

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN JOE - NODE NUMBER 2

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 0

DOWNSTREAM BASIN = 5
NUMBER OF UPSTREAM INFLOWS = 1

UPSTREAM BASINS = 1

AREA OF BASIN = 53.0000 KM**2
AREA OF LAKES = 4.2930 KM**2
AREA OF SWAMPS = 2.5070 KM**2

AREA OF REGULATED LAKE = 5.8000 KM**2

RULE CURVE FOR LAKE OPERATION (M)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN KAWA - NODE NUMBER 3

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 0

DOWNSTREAM BASIN = 6
NUMBER OF UPSTREAM INFLOWS = 0

AREA OF BASIN = 354.8000 KM**2
AREA OF LAKES = 33.6140 KM**2
AREA OF SWAMPS = 4.2760 KM**2

AREA OF REGULATED LAKE = 31.8000 KM**2

MONTH-END LAKE LEVELS (M)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	5.05	4.73	4.44	5.09	5.31	5.37	5.31	5.24	5.08	4.41	4.74	5.08
1976	4.71	4.24	4.80	5.43	5.59	5.43	5.26	5.08	4.94	4.36	4.28	4.47
1977	4.10	3.86	4.45	5.38	5.35	5.27	5.21	5.21	4.94	4.65	5.12	5.35
1978	4.73	4.22	3.72	5.37	5.49	5.61	5.53	5.41	5.06	4.68	4.89	5.09
1979	5.06	4.53	4.63	5.59	5.61	5.58	5.49	5.44	4.92	4.89	4.92	4.79
1980	4.73	4.27	4.77	5.49	5.47	5.72	5.72	5.31	5.12	4.86	5.02	5.05

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN RAGGED - NODE NUMBER 4

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 0

DOWNSTREAM BASIN = 5
NUMBER OF UPSTREAM INFLOWS = 0

AREA OF BASIN = 64.1500 KM**2
AREA OF LAKES = 6.8580 KM**2
AREA OF SWAMPS = 1.2570 KM**2

AREA OF REGULATED LAKE = 6.3000 KM**2

RULE CURVE FOR LAKE OPERATION (M)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN TSC - NODE NUMBER 5

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 0

DOWNSTREAM BASIN = 6
NUMBER OF UPSTREAM INFLOWS = 2

UPSTREAM BASINS = 2 4

AREA OF BASIN = 142.3800 KM**2
AREA OF LAKES = 10.3770 KM**2
AREA OF SWAMPS = 3.1130 KM**2

AREA OF REGULATED LAKE = 12.5000 KM**2

RULE CURVE FOR LAKE OPERATION (M)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

BASIN BAY - NODE NUMBER 6

BASIN REGULATION = 2
EXTERNAL INFLOW FLAG = 0
MEASURED BASIN DISCHARGE FLAG = 1

DOWNSTREAM BASIN = 0
NUMBER OF UPSTREAM INFLOWS = 2

UPSTREAM BASINS = 5 3

AREA OF BASIN = 591.3500 KM**2
AREA OF LAKES = 37.8490 KM**2
AREA OF SWAMPS = 24.4940 KM**2

AREA OF REGULATED LAKE = 68.4000 KM**2

MONTH-END LAKE LEVELS (M)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973	5.21	4.87	4.95	5.18	5.19	5.28	5.22	5.10	5.20	5.04	5.23	5.18
1974	5.17	4.92	4.25	5.28	5.13	5.16	5.10	5.19	5.19	5.13	5.22	5.06
1975	5.07	4.99	4.40	4.88	5.13	5.18	5.22	5.22	5.21	5.16	5.21	5.16
1976	5.03	4.82	4.81	5.18	5.14	5.24	5.17	5.16	5.21	5.19	5.18	5.08
1977	4.92	4.81	4.66	5.25	5.23	5.22	5.19	5.25	5.27	5.14	5.23	5.13
1978	4.89	4.79	4.40	5.21	5.19	5.16	5.18	5.27	5.21	5.16	5.24	5.18
1979	5.16	4.77	4.68	5.29	5.24	4.88	5.22	5.30	5.14	5.20	5.30	5.18
1980	5.05	4.82	4.77	5.13	5.19	5.24	5.32	5.25	5.30	5.18	5.19	5.10

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

COEFFICIENTS FOR RUNOFF PREDICTION EQUATIONS - HISTORIC SEQUENTIAL EQUATIONS

MONTH	A1	A2	A3	A4	A5	A6
JAN	0.244000	0.048000	0.000000	0.025000	0.000660	0.000000
FEB	0.213000	0.042000	0.000000	0.018000	0.049000	0.000000
MAR	1.033000	-0.039000	0.007100	0.000000	0.043000	0.000000
APR	-0.926000	0.529000	0.020000	0.000000	-0.267000	0.262000
MAY	-0.384000	0.051000	0.023000	0.000000	0.213000	-0.108000
JUN	0.071000	0.119000	0.000000	0.000000	0.114000	-0.074000
JUL	0.399000	0.064000	0.000000	0.927000	0.000000	-0.066000
AUG	0.080000	0.051000	0.000000	0.522000	0.000000	-0.038000
SEP	0.050000	0.170000	-0.008600	0.000000	-0.022000	0.000000
OCT	0.064000	0.313000	-0.017000	0.000000	-0.024000	0.000000
NOV	0.060000	0.296000	-0.012000	0.000000	0.000000	0.000000
DEC	0.161000	0.058000	0.000000	0.036000	0.001300	0.000000

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

EVAPORATION COEFFICIENTS (M/MONTH)

DATA SET	APPLICABLE FOR BASINS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	1 2 3 4 5 6	0.0000	0.0000	0.0100	0.0200	0.0800	0.1350	0.1450	0.1200	0.0750	0.0450	0.0150	0.00

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

SET 1 : TEMPERATURE DATA WRT RUNOFF CALCULATION

APPLICABLE FOR 6 BASINS
BASINS = 1 2 3 4 5 6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	51.00	94.00
1971	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34.00	91.00
1972	44.00	0.00	11.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.00	45.00
1973	35.00	3.00	33.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00	81.00
1974	37.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.00	88.00
1975	29.00	2.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.00	153.00
1976	24.00	0.00	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	47.00
1977	3.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.00	16.00
1978	9.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.00	21.80
1979	11.50	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.00	107.00
1980	24.00	0.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	49.00
1981	6.00	4.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00	71.00

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

SET 1 : PRECIPITATION DATA (M/MONTH) WRT RUNOFF CALCULATION

APPLICABLE FOR 6 BASINS
BASINS = 1 2 3 4 5 6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.0610	0.0510	0.0540	0.0640	0.0870	0.0990	0.1330	0.1200	0.1220	0.0880	0.0800	0.0910
1971	0.1060	0.1170	0.0990	0.0500	0.0400	0.0600	0.0620	0.0790	0.0640	0.0600	0.0730	0.1000
1972	0.1250	0.1120	0.0960	0.0640	0.0740	0.0820	0.0960	0.1080	0.1080	0.1030	0.0830	0.0960
1973	0.1240	0.0860	0.0830	0.0680	0.0810	0.1690	0.1370	0.1180	0.0570	0.0610	0.0770	0.0920
1974	0.1200	0.1010	0.0860	0.0780	0.0980	0.0730	0.0650	0.0720	0.0990	0.1170	0.1110	0.0740
1975	0.0790	0.1030	0.0900	0.0610	0.0570	0.0550	0.0660	0.0780	0.0950	0.0840	0.0930	0.1030
1976	0.0990	0.0970	0.1030	0.0690	0.0410	0.0710	0.0610	0.0640	0.0870	0.0910	0.1060	0.1020
1977	0.0990	0.0820	0.0740	0.0580	0.0400	0.0430	0.0520	0.0830	0.1020	0.1060	0.1260	0.1290
1978	0.0840	0.0360	0.0240	0.0430	0.0470	0.0650	0.0720	0.1070	0.1140	0.1060	0.0940	0.0830
1979	0.1220	0.1030	0.0700	0.0960	0.0720	0.0840	0.0850	0.0780	0.0900	0.1080	0.0980	0.0720
1980	0.0600	0.0570	0.0630	0.0800	0.0740	0.0990	0.1050	0.1270	0.1130	0.1140	0.0780	0.0920
1981	0.1030	0.0640	0.0650	0.0780	0.7300	0.0870	0.0690	0.1190	0.1400	0.1600	0.1040	0.0680

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

SET 1 : MONTHLY PRECIPITATION DATA (M/MONTH)

APPLICABLE FOR 6 BASINS
BASINS = 1 2 3 4 5 6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	0.0610	0.0420	0.0600	0.0680	0.1060	0.0910	0.2030	0.0650	0.0970	0.1010	0.0710	0.1120
1971	0.1000	0.1340	0.0640	0.0360	0.0450	0.0750	0.0670	0.0940	0.0310	0.0550	0.0860	0.1140
1972	0.1350	0.0890	0.0640	0.0640	0.0830	0.0800	0.1260	0.1190	0.0790	0.1090	0.0640	0.1280
1973	0.1190	0.0530	0.0770	0.0590	0.1030	0.2350	0.0720	0.0460	0.0550	0.0830	0.0930	0.0910
1974	0.1490	0.0530	0.0550	0.1000	0.0960	0.0500	0.0490	0.1180	0.1300	0.1040	0.1040	0.0440
1975	0.1140	0.0920	0.0660	0.0560	0.0570	0.0530	0.0870	0.0930	0.1050	0.0550	0.1010	0.1060
1976	0.0920	0.1030	0.1140	0.0230	0.0580	0.0830	0.0420	0.0670	0.1520	0.0530	0.1210	0.0830
1977	0.1150	0.0490	0.0590	0.0560	0.0240	0.0620	0.0710	0.1160	0.1180	0.0840	0.1470	0.1100
1978	0.0570	0.0140	0.0350	0.0520	0.0420	0.0880	0.0870	0.1450	0.1110	0.0620	0.0820	0.0830
1979	0.1610	0.0440	0.0910	0.0280	0.1160	0.0530	0.0860	0.0940	0.0900	0.1380	0.0880	0.0550
1980	0.0650	0.0490	0.0740	0.0870	0.0610	0.1370	0.1170	0.1280	0.0960	0.1200	0.0410	0.1430
1981	0.0630	0.0640	0.0680	0.0890	0.0640	0.0900	0.0670	0.2010	0.1820	0.1000	0.4900	0.0430

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

MEASURED BASIN DISCHARGE (M**3/S) FOR BASIN BAY - NODE NUMBER 6

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1970	20.2000	22.2000	22.3000	28.3000	43.6000	13.8000	49.9000	20.4000	11.2000	30.9000	21.3000	25.6000
1971	19.7000	27.3000	36.1000	47.5000	33.6000	11.1000	5.1800	5.7900	13.2000	7.5500	8.3600	10.4000
1972	19.2000	24.0000	31.6000	40.1000	64.3000	18.5000	26.1000	31.9000	16.0000	24.7000	31.9000	21.8000
1973	29.5000	40.9000	57.3000	58.8000	34.7000	31.9000	17.6000	16.5000	15.9000	16.8000	10.7000	25.5000
1974	25.9000	33.3000	40.6000	57.1000	64.7000	19.7000	7.6400	6.8300	12.3000	26.1000	28.4000	22.5000
1975	20.3000	23.1000	40.1000	35.5000	31.5000	4.6200	3.3800	5.0600	13.8000	20.1000	10.4000	32.0000
1976	25.0000	27.6000	50.5000	69.1000	24.0000	8.1900	18.6000	6.3100	6.1800	11.8000	8.1700	12.9000
1977	15.4000	13.8000	41.5000	38.7000	13.9000	4.0400	3.0400	3.2900	14.4000	33.7000	24.1000	27.5000
1978	29.7000	19.5000	27.7000	25.1000	53.4000	11.3000	3.9700	6.3200	19.7000	25.6000	14.7000	21.4000
1979	21.5000	30.7000	50.1000	57.4000	44.7000	15.8000	5.0900	9.5200	22.1000	28.3000	43.1000	40.1000
1980	30.2000	25.1000	23.0000	78.5000	20.6000	22.5000	17.0000	22.8000	24.3000	33.9000	30.3000	24.3000
1981	20.9000	37.1000	52.6000	31.8000	22.3000	13.6000	5.2400	3.9600	61.8000	37.5000	14.6000	16.7000

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 0 : SUMMARY OF MONTHLY SIMULATION - YEAR 1975 , JAN

BASIN NAME	NODE	NET BASIN EVAP LOSS (M)	RUNOFF TEMP DEGREE C	RUNOFF PRECIP (M)	BASIN RUNOFF (M**3/S)	UNIT RUNOFF (MM)	UPSTREAM INFLOW (M**3/S)	BASIN DISCHARGE (M**3/S)	LAKE ELEVATION INITIAL (M)	LAKE ELEVATION FINAL (M)	CHANGE IN LAKE ELEV (M)
BURNT	1	-0.1140	29.0000	0.0790	0.5705	30.8987	0.0000	0.1568	29.8700	30.0994	0.229
JOE	2	-0.1140	29.0000	0.0790	0.6349	32.0841	0.1568	1.0385	421.5500	421.5500	0.000
KAWA	3	-0.1140	29.0000	0.0790	3.0947	23.3619	0.0000	5.9916	5.1800	5.0500	-0.130
RAGGED	4	-0.1140	29.0000	0.0790	0.7969	33.2714	0.0000	0.6605	431.8100	431.9820	0.172
TSC	5	-0.1140	29.0000	0.0790	1.2386	23.2998	1.6990	3.7807	417.5800	417.5133	-0.066
BAY	6	-0.1140	29.0000	0.0790	4.1228	18.6735	9.7723	16.5510	5.0600	5.0700	0.010

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : SUMMARY OF MONTHLY SIMULATION - YEAR 1975 , JAN

BASIN NAME	NODE	NET BASIN EVAP LOSS (M)	RUNOFF TEMP DEGREE C	RUNOFF PRECIP (M)	BASIN RUNOFF (M**3/S)	UNIT RUNOFF (MM)	UPSTREAM INFLOW (M**3/S)	BASIN DISCHARGE (M**3/S)	LAKE ELEVATION INITIAL (M)	LAKE ELEVATION FINAL (M)	CHANGE I LAKE ELE (M)
BURNT	1	-0.1140	29.0000	0.0790	0.7750	41.9748	0.0000	0.3613	29.8700	30.0994	0.229
JOE	2	-0.1140	29.0000	0.0790	0.8625	43.5852	0.3613	1.4706	421.5500	421.5500	0.000
KAWA	3	-0.1140	29.0000	0.0790	4.2040	31.7363	0.0000	7.1010	5.1800	5.0500	-0.130
RAGGED	4	-0.1140	29.0000	0.0790	1.0825	45.1981	0.0000	0.9461	431.8100	431.9820	0.172
TSC	5	-0.1140	29.0000	0.0790	1.6826	31.6520	2.4167	4.9424	417.5800	417.5133	-0.066
BAY	6	-0.1140	29.0000	0.0790	5.6007	25.3673	12.0434	20.3000	5.0600	5.0700	0.010

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 0 : SUMMARY OF MONTHLY SIMULATION - YEAR 1975 , FEB

BASIN NAME	NODE	NET BASIN EVAP LOSS (M)	RUNOFF TEMP DEGREE C	RUNOFF PRECIP (M)	BASIN RUNOFF (M**3/S)	UNIT RUNOFF (MM)	UPSTREAM INFLOW (M**3/S)	BASIN DISCHARGE (M**3/S)	LAKE ELEVATION INITIAL (M)	LAKE ELEVATION FINAL (M)	CHANGE IN LAKE ELEV (M)
BURNT	1	-0.0920	2.0000	0.1030	0.9386	45.9186	0.0000	0.4540	30.0994	30.3135	0.2141
JOE	2	-0.0920	2.0000	0.1030	1.0266	46.8572	0.4540	2.3133	421.5500	421.2946	-0.2553
KAWA	3	-0.0920	2.0000	0.1030	5.8639	39.9832	0.0000	11.2796	5.0500	4.7300	-0.3200
RAGGED	4	-0.0920	2.0000	0.1030	1.2675	47.7995	0.0000	1.0890	431.9820	432.1425	0.1606
TSC	5	-0.0920	2.0000	0.1030	2.3500	39.9290	3.4023	7.0476	417.5133	417.3546	-0.1587
BAY	6	-0.0920	2.0000	0.1030	8.8681	36.2792	18.3272	32.0584	5.0700	4.9900	-0.0800

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : SUMMARY OF MONTHLY SIMULATION - YEAR 1975 , FEB

BASIN NAME	NODE	NET BASIN EVAP LOSS (M)	RUNOFF TEMP DEGREE C	RUNOFF PRECIP (M)	BASIN RUNOFF (M**3/S)	UNIT RUNOFF (MM)	UPSTREAM INFLOW (M**3/S)	BASIN DISCHARGE (M**3/S)	LAKE ELEVATION INITIAL (M)	LAKE ELEVATION FINAL (M)	CHANGE I LAKE ELE (M)
BURNT	1	-0.0920	2.0000	0.1030	0.5247	25.6693	0.0000	0.0401	30.0994	30.3135	0.214
JOE	2	-0.0920	2.0000	0.1030	0.5739	26.1940	0.0401	1.4467	421.5500	421.2946	-0.255
KAWA	3	-0.0920	2.0000	0.1030	3.2780	22.3513	0.0000	8.6937	5.0500	4.7300	-0.320
RAGGED	4	-0.0920	2.0000	0.1030	0.7086	26.7207	0.0000	0.5300	431.9820	432.1425	0.160
TSC	5	-0.0920	2.0000	0.1030	1.3137	22.3210	1.9767	4.5857	417.5133	417.3546	-0.158
BAY	6	-0.0920	2.0000	0.1030	4.9574	20.2807	13.2795	23.1000	5.0700	4.9900	-0.080

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - RURNT ; NODE NUMBER 1

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975 CALC	0.361	0.040	0.811	0.936	1.182	0.116	0.209	0.083	3.846	2.008	0.000	0.712	0.859
1976 CALC	0.236	0.113	1.871	1.814	0.705	0.265	0.938	0.042	3.634	1.713	0.000	0.000	0.944
1977 CALC	0.000	0.000	0.905	1.104	0.329	0.000	0.090	0.139	3.860	2.713	0.678	0.549	0.864
1978 CALC	0.181	0.000	0.157	0.539	1.956	0.381	0.185	0.276	3.942	2.376	0.064	0.288	0.862
1979 CALC	0.478	0.000	1.935	2.052	1.407	0.090	0.684	0.380	3.828	2.896	1.180	0.772	1.308
1980 CALC	0.757	0.000	0.575	2.388	0.631	1.044	0.987	0.612	4.336	2.788	0.571	0.341	1.253
MEAN CALC	0.336	0.026	1.042	1.472	1.035	0.316	0.516	0.255	3.908	2.416	0.416	0.444	
SDEV CALC	0.263	0.046	0.715	0.719	0.597	0.382	0.403	0.215	0.233	0.473	0.479	0.291	
SKEW CALC	0.586	1.901	0.386	-0.011	0.541	1.809	0.197	0.931	1.354	-0.642	0.770	-0.444	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - JOE ; NODE NUMBER 2

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975	CALC	1.471	1.447	3.039	0.868	2.698	0.401	0.511	0.215	4.466	2.745	0.731	2.330	1.743
1976	CALC	1.244	1.593	5.209	2.777	1.671	0.655	2.041	0.168	3.973	2.152	0.361	0.667	1.876
1977	CALC	0.410	1.030	4.411	1.232	0.928	0.119	0.303	0.294	4.478	4.146	2.116	1.951	1.785
1978	CALC	1.196	1.189	2.029	0.076	4.398	0.893	0.465	0.533	4.656	3.493	0.957	1.455	1.778
1979	CALC	1.631	1.344	5.426	3.226	3.064	0.341	1.495	0.821	4.451	4.436	3.253	2.507	2.667
1980	CALC	2.402	1.356	2.686	3.848	1.501	2.191	2.088	1.273	5.478	4.247	2.072	1.444	2.549
MEAN	CALC	1.392	1.327	3.800	2.004	2.377	0.767	1.150	0.551	4.584	3.537	1.582	1.726	
SDEV	CALC	0.649	0.197	1.412	1.490	1.267	0.717	0.823	0.429	0.494	0.920	1.088	0.678	
SKEW	CALC	0.094	-0.314	-0.006	-0.050	0.672	1.792	0.203	1.081	1.202	-0.708	0.526	-0.500	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - KAWA ; NODE NUMBER 3

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975	CALC	7.101	8.694	8.542	5.905	10.957	2.088	2.201	1.898	3.549	10.270	0.404	6.000	5.634
1976	CALC	9.494	10.398	8.806	13.500	6.507	5.383	7.403	3.264	1.766	7.552	3.074	1.661	6.567
1977	CALC	6.521	5.167	4.626	5.723	3.842	2.445	1.598	1.144	4.909	10.156	3.225	5.445	4.567
1978	CALC	12.254	9.474	8.361	4.723	8.150	2.925	2.380	3.195	6.509	9.326	2.936	4.318	6.213
1979	CALC	6.244	10.454	11.627	10.483	14.058	2.790	5.494	3.935	7.944	7.674	12.635	12.066	8.784
1980	CALC	8.557	9.475	1.366	15.462	7.584	5.836	6.322	9.632	7.099	9.991	7.253	6.090	7.889
MEAN	CALC	8.362	8.943	7.221	9.299	8.516	3.578	4.233	3.845	5.296	9.161	4.921	5.930	
SDEV	CALC	2.278	1.964	3.633	4.523	3.566	1.607	2.470	3.011	2.341	1.244	4.372	3.427	
SKEW	CALC	1.084	-1.864	-0.782	0.419	0.487	0.858	0.197	1.827	-0.542	-0.708	1.294	1.110	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - RAGGED ; NODE NUMBER 4

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975 CALC	0.946	0.530	1.241	0.943	1.852	0.565	0.461	1.709	1.620	0.204	0.608	1.736	1.035
1976 CALC	0.826	0.633	2.713	1.840	0.983	0.676	1.611	1.733	1.323	0.000	0.040	0.572	1.079
1977 CALC	0.068	0.089	2.695	1.005	0.432	0.298	0.346	1.721	1.620	1.019	1.448	1.514	1.021
1978 CALC	0.852	0.302	0.800	0.207	3.359	0.873	0.431	1.842	1.734	0.660	0.806	1.234	1.092
1979 CALC	0.982	0.486	2.731	2.469	1.998	0.474	1.177	2.187	1.618	1.137	2.219	1.934	1.618
1980 CALC	1.643	0.503	1.236	2.510	0.810	1.737	1.565	2.448	2.214	1.053	1.536	1.106	1.530
MEAN CALC	0.886	0.424	1.903	1.496	1.572	0.771	0.932	1.940	1.688	0.679	1.110	1.350	
SDEV CALC	0.502	0.196	0.902	0.927	1.066	0.511	0.590	0.308	0.292	0.480	0.777	0.489	
SKEW CALC	-0.268	-1.127	-0.134	-0.159	0.911	1.713	0.220	1.171	1.156	-0.629	0.066	-0.574	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - TSC ; NODE NUMBER 5

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975 CALC	4.942	4.586	7.653	5.030	9.345	1.838	1.549	2.287	6.942	4.299	3.464	8.340	5.023
1976 CALC	4.415	4.724	15.074	11.114	5.715	2.453	5.766	2.271	5.412	2.763	1.559	3.084	5.363
1977 CALC	1.631	2.739	13.351	6.211	3.328	0.830	1.009	2.416	6.940	8.320	7.513	6.937	5.102
1978 CALC	4.312	3.418	5.176	2.781	15.543	3.208	1.443	3.012	7.493	6.512	4.323	5.572	5.233
1979 CALC	5.267	4.041	14.707	12.267	10.158	1.596	4.347	4.176	6.938	8.959	11.079	8.857	7.699
1980 CALC	7.489	4.045	7.811	14.001	5.042	7.025	6.012	5.410	9.910	8.503	7.709	5.373	7.361
MEAN CALC	4.676	3.925	10.629	8.568	8.188	2.825	3.354	3.262	7.273	6.559	5.941	6.360	
SDEV CALC	1.887	0.744	4.250	4.500	4.448	2.209	2.292	1.277	1.470	2.536	3.463	2.136	
SKEW CALC	-0.259	-0.729	-0.137	-0.077	0.838	1.764	0.200	1.173	1.116	-0.729	0.299	-0.404	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : DISCHARGE (M**3/S) SUMMARY FOR BASIN - BAY : NODE NUMBER 6

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1975	CALC	20.300	23.100	40.100	35.406	31.500	4.620	3.380	5.060	13.800	20.100	10.457	32.000	19.985
	MEAS	20.300	23.100	40.100	35.500	31.500	4.620	3.380	5.060	13.800	20.100	10.400	32.000	19.988
1976	CALC	25.000	27.593	50.500	69.100	24.000	8.490	18.600	6.310	6.180	12.050	9.010	13.700	22.544
	MEAS	25.000	27.600	50.500	69.100	24.000	8.490	18.600	6.310	6.180	11.800	8.170	12.900	22.387
1977	CALC	16.165	14.105	41.500	38.444	13.700	4.058	3.040	3.290	14.400	33.700	24.100	27.500	19.517
	MEAS	15.400	13.800	41.500	38.700	13.900	4.040	3.040	3.290	14.400	33.700	24.100	27.500	19.448
1978	CALC	29.609	19.480	27.700	22.920	53.400	11.300	3.970	6.320	19.700	25.600	14.700	21.400	21.342
	MEAS	29.700	19.500	27.700	25.100	53.400	11.300	3.970	6.320	19.700	25.600	14.700	21.400	21.533
1979	CALC	21.500	30.459	50.476	57.400	44.700	15.800	5.090	9.520	22.100	28.300	43.100	40.100	30.712
	MEAS	21.500	30.700	50.100	57.400	44.700	15.800	5.090	9.520	22.100	28.300	43.100	40.100	30.701
1980	CALC	30.130	24.782	23.000	78.500	20.600	22.500	17.000	22.800	24.300	33.900	30.124	24.300	29.328
	MEAS	30.200	25.100	23.000	78.500	20.600	22.500	17.000	22.800	24.300	33.900	30.300	24.300	29.375
MEAN	CALC	23.784	23.253	38.879	50.295	31.350	11.128	8.513	8.883	16.747	25.608	21.915	26.500	
MEAN	MEAS	23.683	23.300	38.817	50.717	31.350	11.125	8.513	8.883	16.747	25.567	21.795	26.367	
SDEV	CALC	5.497	5.849	11.446	21.500	15.090	7.078	7.245	7.116	6.637	8.434	13.197	9.065	
SDEV	MEAS	5.749	6.020	11.370	20.913	15.090	7.081	7.245	7.116	6.637	8.514	13.397	9.294	
SKEW	CALC	-0.075	-0.540	-0.451	0.120	0.537	0.783	0.950	2.024	-0.624	-0.770	0.789	0.178	
SKEW	MEAS	-0.191	-0.580	-0.465	0.193	0.537	0.781	0.950	2.024	-0.624	-0.795	0.740	0.074	
STD ERR		0.387	0.251	0.188	1.098	0.000	0.009	0.000	0.000	0.000	0.125	0.430	0.400	

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - BURNT ; NODE NUMBER 1

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	CALC	30.099	30.314	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.609	29.870
1976	CALC	30.099	30.314	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.524	29.729
1977	CALC	29.884	30.001	30.551	30.780	30.780	30.775	30.780	30.780	29.830	29.387	29.624	29.870
1978	CALC	30.099	30.236	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.624	29.870
1979	CALC	30.099	30.285	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.624	29.870
1980	CALC	30.099	30.289	30.551	30.780	30.780	30.780	30.780	30.780	29.830	29.387	29.624	29.870
MEAN	CALC	30.064	30.240	30.551	30.780	30.780	30.779	30.780	30.780	29.830	29.387	29.605	29.846
SDEV	CALC	0.088	0.120	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.040	0.058

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 ; MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - JOE ; NODE NUMBER 2

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
1976	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
1977	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
1978	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
1979	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
1980	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
MEAN	CALC	421.550	421.295	421.000	421.900	421.850	421.850	421.850	421.850	421.700	421.550	421.550	421.550
SDEV	CALC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - KAWA ; NODE NUMBER 3

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975 CALC	5.050	4.730	4.440	5.090	5.310	5.370	5.310	5.240	5.080	4.410	4.740	5.080
1976 CALC	4.710	4.240	4.800	5.430	5.590	5.430	5.260	5.080	4.940	4.360	4.280	4.470
1977 CALC	4.100	3.860	4.450	5.236	5.350	5.270	5.210	5.210	4.940	4.650	5.120	5.350
1978 CALC	4.730	4.220	3.720	4.273	5.490	5.610	5.530	5.410	5.060	4.680	4.890	5.090
1979 CALC	5.060	4.530	4.630	5.590	5.610	5.580	5.490	5.440	4.920	4.890	4.920	4.790
1980 CALC	4.730	4.270	4.770	5.490	5.470	5.720	5.720	5.310	5.120	4.860	5.020	5.050
MEAN CALC	4.730	4.308	4.468	5.185	5.470	5.497	5.420	5.282	5.010	4.642	4.828	4.972
SDEV CALC	0.349	0.297	0.397	0.482	0.122	0.168	0.194	0.134	0.086	0.221	0.297	0.303

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - RAGGED ; NODE NUMBER 4

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810
1976 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.555	431.706	431.810
1977 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810
1978 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810
1979 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810
1980 CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.605	431.706	431.810
MEAN CALC	431.982	432.143	432.320	432.492	432.670	432.670	432.670	432.040	431.500	431.596	431.706	431.810
SDEV CALC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - TSC ; NODE NUMBER 5

YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
1976	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
1977	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
1978	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
1979	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
1980	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
MEAN	CALC	417.513	417.355	417.210	417.880	417.820	417.820	417.820	417.820	417.786	417.717	417.650	417.580
SDEV	CALC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SOUTH BRANCH MUSKOKA RIVER - HISTORIC SEQUENTIAL RUNOFF EQUATIONS
VERIFICATION RUNS - ACTUAL LAKE LEVELS USED AT KAWAGAMA AND BAYS
SIMULATION PERIOD 1975 - 1980

ITERATION 3 : MONTH-END LAKE LEVEL (M) SUMMARY FOR BASIN - BAY ; NODE NUMBER 6

YEAR TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1975 CALC	5.070	4.990	4.400	4.880	5.130	5.180	5.220	5.220	5.210	5.160	5.210	5.160
1976 CALC	5.030	4.820	4.810	5.180	5.140	5.240	5.170	5.160	5.210	5.190	5.180	5.080
1977 CALC	4.920	4.810	4.660	5.250	5.230	5.220	5.190	5.250	5.270	5.140	5.230	5.130
1978 CALC	4.890	4.790	4.400	5.210	5.190	5.160	5.180	5.270	5.210	5.160	5.240	5.180
1979 CALC	5.160	4.770	4.680	5.290	5.240	4.880	5.220	5.300	5.140	5.200	5.300	5.180
1980 CALC	5.050	4.820	4.770	5.130	5.190	5.240	5.320	5.250	5.300	5.180	5.190	5.100
MEAN CALC	5.020	4.833	4.620	5.157	5.187	5.153	5.217	5.242	5.223	5.172	5.225	5.138
SDEV CALC	0.100	0.079	0.179	0.146	0.045	0.138	0.055	0.048	0.056	0.022	0.043	0.042

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TABLE F-8 OUTPUT DATA FILE TO BE USED AS INPUT TO THE SERPENT RIVER MODEL

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    6
    1   BURNT
    2    0
    2   JOE
    5    1    1
    3   KAWA
    6    0
    4   RAGGED
    5    0
    5   TSC
    6    2    2    4
    6   BAY
    0    2    5    3
1975    1    0.3613    1.4706    7.1010    0.9461    4.9424   20.3000
1975    2    0.0401    1.4467    8.6937    0.5300    4.5857   23.1000
1975    3    0.8106    3.0387    8.5419    1.2406    7.6528   40.1000
1975    4    0.9364    0.8677    5.9051    0.9429    5.0299   35.4061
1975    5    1.1818    2.6978   10.9573    1.8515    9.3452   31.5000
1975    6    0.1162    0.4006    2.0881    0.5654    1.8382    4.6200
1975    7    0.2094    0.5109    2.2014    0.4605    1.5487    3.3800
1975    8    0.0830    0.2130    1.8978    1.7090    2.2868    5.0600
1975    9    3.8456    4.4661    3.5487    1.6198    6.9418   13.8000
1975   10    2.0085    2.7449   10.2698    0.2043    4.2989   20.1000
1975   11    0.0000    0.7311    0.4042    0.6080    3.4638   10.4567
1975   12    0.7117    2.3303    5.9997    1.7365    8.3395   32.0000
1976    1    0.2357    1.2440    9.4943    0.8257    4.4150   25.0000
1976    2    0.1133    1.5931   10.3982    0.6331    4.7244   27.5932
1976    3    1.8707    5.2085    8.8061    2.7128   15.0740   50.5000
1976    4    1.8141    2.7773   13.4998    1.8405   11.1144   69.1000
1976    5    0.7048    1.6708    6.5068    0.9831    5.7150   24.0000
1976    6    0.2647    0.6554    5.3830    0.6759    2.4528    8.4900
1976    7    0.9376    2.0412    7.4027    1.6107    5.7657   18.6000
1976    8    0.0423    0.1682    3.2644    1.7325    2.2710    6.3100
1976    9    3.6340    3.9733    1.7664    1.3232    5.4121    6.1800
1976   10    1.7125    2.1524    7.5524    0.0000    2.7627   12.0497
1976   11    0.0000    0.3614    3.0741    0.0398    1.5589    9.0099
1976   12    0.0000    0.6670    1.6614    0.3723    3.0839   13.6996
1977    1    0.0000    0.4099    6.5211    0.0684    1.6313   16.1651
1977    2    0.0000    1.0299    5.1669    0.0888    2.7388   14.1048
1977    3    0.9045    4.4111    4.6263    2.6949   13.3507   41.5000
1977    4    1.1043    1.2321    5.7233    1.0052    6.2112   38.4435
1977    5    0.3288    0.9276    3.8417    0.4324    3.3279   13.9000
1977    6    0.0000    0.1188    2.4453    0.2978    0.8299    4.0383
1977    7    0.0905    0.3031    1.5977    0.3459    1.0095    3.0400
1977    8    0.1392    0.2942    1.1440    1.7206    2.4163    3.2900
1977    9    3.8602    4.4777    4.9089    1.6205    6.9404   14.4000
1977   10    2.7127    4.1433   10.1558    1.0186    8.3199   33.7000
1977   11    0.6782    2.1163    3.2248    1.4485    7.5134   24.1000
1977   12    0.5487    1.9512    5.4447    1.5138    6.9369   27.5000
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TABLE F-8 CONT'D OUTPUT DATA FILE TO BE USED AS INPUT TO THE SERPENT RIVER MODEL

1978	1	0.1808	1.1959	12.2544	0.8519	4.3120	29.6086
1978	2	0.0000	1.1890	9.4736	0.3019	3.4175	19.4802
1978	3	0.1575	2.0286	8.3607	0.7998	5.1762	27.7000
1978	4	0.5388	0.0755	4.7228	0.2068	2.7812	22.9201
1978	5	1.9564	4.3982	8.1503	3.3595	15.5425	53.4000
1978	6	0.3811	0.8926	2.9252	0.8726	3.2080	11.3000
1978	7	0.1849	0.4646	2.3801	0.4307	1.4426	3.9700
1978	8	0.2757	0.5327	3.1949	1.8421	3.0120	6.3200
1978	9	3.9418	4.6561	6.5095	1.7338	7.4934	19.7000
1978	10	2.3760	3.4931	9.3260	0.6598	6.5120	25.6000
1978	11	0.0643	0.9571	2.9359	0.8062	4.3228	14.7000
1978	12	0.2882	1.4555	4.3184	1.2343	5.5722	21.4000
1979	1	0.4782	1.6308	6.2437	0.9818	5.2665	21.5000
1979	2	0.0000	1.3440	10.4536	0.4864	4.0409	30.4593
1979	3	1.9352	5.4263	11.6271	2.7313	14.7070	50.4762
1979	4	2.0518	3.2257	10.4831	2.4685	12.2674	57.4000
1979	5	1.4071	3.0641	14.0583	1.9978	10.1578	44.7000
1979	6	0.0897	0.3410	2.7904	0.4741	1.5956	15.8000
1979	7	0.6841	1.4954	5.4942	1.1772	4.3467	5.0900
1979	8	0.3797	0.8244	3.9346	2.1866	4.1758	9.5200
1979	9	3.8282	4.4514	7.9438	1.6176	6.9380	22.1000
1979	10	2.8958	4.4338	7.6737	1.1370	8.9592	28.3000
1979	11	1.1801	3.2534	12.6345	2.2188	11.0786	43.1000
1979	12	0.7718	2.5072	12.0638	1.9340	8.8369	40.1000
1980	1	0.7574	2.4024	8.5570	1.6428	7.4894	30.1299
1980	2	0.0000	1.3564	9.4749	0.5031	4.0454	24.7817
1980	3	0.5754	2.6855	1.3657	1.2357	7.8110	23.0000
1980	4	2.3884	3.8482	15.4622	2.5095	14.0010	78.5000
1980	5	0.6305	1.5015	7.5841	0.8103	5.0421	20.6000
1980	6	1.0439	2.1907	5.8357	1.7374	7.0254	22.5000
1980	7	0.9868	2.0876	6.3221	1.5648	6.0121	17.0000
1980	8	0.6119	1.2729	9.6318	2.4480	5.4097	22.8000
1980	9	4.3357	5.4781	7.0995	2.2137	9.9099	24.3000
1980	10	2.7882	4.2473	9.9912	1.0529	8.5035	33.9000
1980	11	0.5712	2.0721	7.2534	1.5361	7.7086	30.1244
1980	12	0.3410	1.4438	6.0901	1.1064	5.3733	24.3000

TABLE F-9 SUMMARY OF CALCULATED DISCHARGE FROM BASIN
TO BE USED AS INPUT FILE FOR DOWNSTREAM BASINS

	6	6	BAY	BASIN DISCHARGE								
1975	20.300	23.100	40.100	35.406	31.500	4.620	3.380	5.060	13.800	20.100	10.457	32.000
1976	25.000	27.593	50.500	69.100	24.000	8.490	18.600	6.310	6.180	12.050	9.010	13.700
1977	16.165	14.105	41.500	38.444	13.900	4.058	3.040	3.290	14.400	33.700	24.100	27.500
1978	29.609	19.480	27.700	22.920	53.400	11.300	3.970	6.320	19.700	25.600	14.700	21.400
1979	21.500	30.459	50.476	57.400	44.700	15.800	5.090	9.520	22.100	28.300	43.100	40.100
1980	30.130	24.782	23.000	78.500	20.600	22.500	17.000	22.800	24.300	33.900	30.124	24.300

DATE DUE		

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